ISSN 0014-5602

FAO Fisheries Synopsis No. 158

SYNOPSIS OF BIOLOGICAL DATA ON THE TOR MAHSEER *Tor tor* (Hamilton, 1822)

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FIR/S158

SAST - *Tor tor* x,xx(xx)xxx,xx

SYNOPSIS OF BIOLOGICAL DATA ON THE TOR MAHSEER *Tor tor* (Hamilton, 1822)

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INDIA

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

ROME, 2003

ISBN 92-5-104933-5

PREPARATION OF THIS SYNOPSIS

The present document was included in the FAO Species Series in view of the importance of ***Tor tor*** as a food and game fish of India.

This paper is based on data collected by the author and on information compiled from various other sources. The synopsis was prepared by the author with the assistance of N. P. Shrivastava and K. Manjhi of the Reservoir Fisheries Research Centre of the Central Inland Capture Fisheries Research Institute, Hoshangabad (Madhya Pradesh), India.

ACKNOWLEDGEMENTS

I am highly indebted to the Food and Agriculture Organization of the United Nations for giving me the opportunity of writing this Synopsis and reaching an international audience. I am also grateful to the Director of Central Inland Capture Fisheries Research Institute (CICFRI), Barrackpore (West Bengal) for permitting me to do this task. I will be failing in my duty if I forget to acknowledge the valuable guidance received from Shri. S.J. Karamchandani, the then Officer-In-Charge, Narmada Tapti unit of CICFRI, Hoshangabad (Madhya Pradesh) while carrying out the work on biological studies on ***Tor tor*** (Hamilton, 1822) from Narmada River. Special gratitude is due to my son Chandrakant Desai and his staff for their remarkable help in final typing and submitting the Synopsis and taking care of correspondence with FAO. This work, utilized for my Ph.D. thesis and later included in this synopsis, constitutes the main part of the publication. I am also thankful to the entire staff of Narmada-Tapti Unit for helping me in collection and analysis of data in the field and laboratory.

Project Manager: M. Lamboeuf, J. Lleonart (FAO, Rome) and P. Oliver (IEO, Palma de Mallorca).

Technical Editor: T. Petr, Toowoomba QLD 4350, Australia.

Scientific Reviser: N. De Angelis (FAO, Rome).

Scientific Illustrator: E. D’Antoni (FAO, Rome).

Page Composition: G. Sciarappa Demuro and M. Kautenberger-Longo (FAO, Rome).

Cover Illustration: E. D’Antoni (FAO, Rome).

Desai, V.R.

Synopsis of biological data on the tor mahseer *Tor tor* (Hamilton, 1822).

FAO Fisheries Synopsis. No. 158. Rome, FAO. 2003. 36p.

ABSTRACT

Among Indian mahseers, Tor mahseer ***Tor tor*** (Hamilton, 1822) is the most important food and game fish of India after ***Tor putitora*** (Hamilton, 1822). It constitutes an outstanding fishery in the Narmada River in central India. It has also settled in some Indian reservoirs which have been stocked with this fish. However, the building of dams across certain rivers has created reservoirs that have destroyed the natural breeding grounds of the fish and caused mortality of brood and juvenile fish indiscriminately. The mahseer fishery of India is further declining as a result of low recruitment of the fish. Stocking rivers and reservoirs with mahseer is therefore essential to restore the fishery. This synopsis is the compilation of biological data for ***Tor tor – Tor mahseer*** collected from different sources. The detailed biological information on ***Tor tor***, including the feeding habits, breeding and growth patterns contained in this synopsis, will be useful in planning the development of the mahseer fishery in India.

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INTRODUCTION

The genus ***Tor***, called 'mahseer' in India, Pakistan, Nepal and Bhutan, is widespread in southern Asia, from Afghanistan in the west, to Thailand and Malaysia in the east, and also present in China. The genus includes ***Tor tor*** (Hamilton) and nine other species. Mahseers are well known as game and food fish, and they are favoured particularly by the people of the Himalayan foothills of northern and eastern India. Thomas (1897) and McDonald (1948) narrated in detail their sporting and fighting nature and how to fish them.

1. IDENTITY

1.1 Nomenclature

1.1.1 Scientific name

Cyprinus tor (Hamilton, 1822) (type locality, R. Mahananda).

The species ***Cyprinus tor*** was first described from the Mahananda River by Hamilton (1822). He included under the genus ***Cyprinus*** two other species, i.e. ***Cyprinus putitora*** and ***C. mosal***. Drawings of ***C. tor*** and ***C. mosal*** were published by Gray (1834), with the former species described as ***Tor hamiltoni*** and the latter as ***Cyprinus mosal***. While Günther (1868) considered ***C. tor*** to be synonymous with ***Barbus mosal*** (Hamilton), the majority of the later workers followed Day (1878) and used ***Barbus tor*** (Hamilton) in a very wide sense to include all types of large scaled barbels of India. Hora and Mukerji (1936), based on their collections from Eastern Doons, assigned a definite specific limit to Hamilton's ***C. tor***. While the large-scaled barbels have been variously assigned to the genera ***Barbus*** Cuvier, ***Labeobarbus*** Rüppel, ***Barbodes*** Bleeker, ***Tor*** Gray, etc., according to modern classification they are placed in the genus ***Tor*** Gray, with ***Cyprinus tor*** Hamilton (=***Tor hamilton*** (Gray) as the genotype.

1.1.2 Synonyms

1822 ***Cyprinus tor*** Hamilton, Fish Ganges, pp.305, 330 (type locality Mahananda River)

1834 ***Tor hamiltoni*** Gray, *Ill. Ind. Zool.*, 2, pl.36, fig.1

1839 ***Barbus megalepis*** McClelland, *Asiat. Res.*,19, pp.271, 337 (northern parts of Bengal)

1839 ***Barbus hexastichus*** McClelland, *Asiat. Res.*, 19, pp.269, 333, pl.39, fig.2 (big rivers in the plains of India)

1878 ***Barbus tor*** Day, *Fish. India*, p.564

1878 ***Barbus hexastichus*** Day, *Fish. India,* p.564

1935 ***Barbus tor***, Hora and Mukherjee, *Rec. Indian Mus.*, 37, p.383 (Naga Hills)

1941 ***Barbus tor mosal***, Hora, *J. Bombay nat. Hist. Soc.*, 41, p.784, pl. & II, figs. 1-5 (Assam)

1941 ***Barbus (Tor) tor***, Hora, *J. Bombay nat. Hist. Soc.*, 41, p.518, pl.1,2,3 text fig.

1959 ***Tor tor*** Misra, *Rec. Indian Mus.*, 57 (1-4), pp.150-151

1968 ***Tor tor*** Srivastava, Fishes of Eastern Uttar Pradesh, p.57, fig. 37

1974 ***Tor tor*** Menon, A checklist of the Himalayan and Indo-Gangetic plains fishes, Spl. Pub. (1): *J. Ind. Fish. Soc. India*, p.46

1979 ***Tor tor*** Kulkarni, *J. Bombay nat. Hist. Soc.*, 75(3): 651-660

1982 ***Tor tor*** Sen and Jayaram, *Rec. Zool. Surv. India, Occ. Paper* No. 39, pp.2-4, figs 1-2.

1.1.3 Etymology and common names

Thomas (1873) and Lacy and Cretin (1905) noted that the name 'mahseer' is perhaps derived from the Hindustani word maha = great and sir (pronounced seer) = head. A friend of Thomas, a great angler and well-known Persian scholar, wrote to him that the name 'mahseer' was derived from two Persian words, mahi = fish, and sher = lion, in recognition of its gameness. A third derivation is from 'mahasaula', big-scaled, because mahseer has bigger scales than any other freshwater fish in India. A fourth derivation is from 'matsya', which is the Sanskrit word for 'fish' and is used in the Vedas. As mahseer is a sacred fish, preserved and protected near many Hindu temples, Brahmans call it 'mahsia', meaning a fish of excellence. However, it has also been stated that the word 'mahseer' has no phonetic or etymological resemblance to the Sanskrit word 'matsya' and that mahseer is not a big-headed fish. The most probable derivation is that the word 'mahseer' is the corruption of the Persian 'mahisher', referring to its fighting and sporting character.

The standard common and vernacular names are given in **Table 1**.

1.2 Taxonomy

1.2.1 Definition

For a number of years almost all carps with big scales and barbels and a large size with more or less similar morphological characters were regarded as mahseers. This was later restricted to more definite features as follows:

Carp with big scales, fleshy lips continuous at the angles of the mouth with an interrupted fold or groove across the lower jaw, two pairs of big barbels, lateral-line scales ranging from 22 to 28, and length of head equal to or greater or less than the depth of body are considered taxonomically as true mahseers and are included under the genus ***Tor***.

Table 1. Standard and Vernacular Names of ***Tor*** spp.

Country	Standard common names	Vernacular names
Bangladesh		
Bhutan	Mahseer	Jantura
India	Mahseer	Putitor (Goalpara); Sahara and Turiya (Purneah, Bihar); Masal (Kosi R., Bihar); Kajra (Daudnagar, Sone R., U.P.); Burapatra, Junaga, Peetia (Assam); Naharam (Hindi); Kukhiah (Punjab); Kendi, Bommin, Poomeen-Candee Peruval, Harale-minu, Hallamin (Karnatake, Canarese); Meruval (Malayalam); Heragalu, Poo-meen, Peruval - (Telugu); Kudis, Kadehi, Barse Masla - (Marathi); Mahasol (W. Bengal); Badas (Narmada R., Hoshangabad M.P.)
Pakistan	Mahseer	Kurreah (Sind)
Myanmar		
Nepal	Mahseer	Sor - Maccha; Sahar
Sri Lanka		Kuriah, Lela

Misra (1959) classified this genus as:

Phylum Vertebrata
Subphylum Craniata
Superclass Gnathostomata
Series Pisces
Class Teleostomi
Subclass Actinopterygii
Order Cypriniformes
Division Cyprini
Suborder Cyprinoidei
Family Cyprinidae
Genus ***Tor***
Species ***Tor tor*** (Hamilton) 1822

1.2.2 Author of generic name

Hamilton (1822) first grouped mahseers separately and placed them in the genus ***Cyprinus***; he recognized three species of mahseers viz., ***Cyprinus tor, Cyprinus putitora*** and ***Cyprinus mosal***. Later workers placed these fishes in two distinct genera viz., ***Barbus*** Cuvier in 1817, and ***Tor*** Gray in 1834.

Hora (refs. 1939 to 1943) was of the opinion that unless someone revises the whole ***Barbus*** complex, it is premature to split ***Barbus*** into more genera. But he recognized that mahseer is probably at least subgenerically distinct from ***Barbus*** and that ***Tor*** can be used provisionally as a subgeneric name. Misra (1959) has classified all the mahseers under a separate genus ***Tor***.

1.2.3 Description (Figure 1)

D. 12(3/9); P. 19; V. 9; A.7-8(2-3/5), C. 19; L. 1.22-27, L.tr. 4¼/2½

Head slightly shorter than depth; dorsal profile more sharply arched than ventral profile, lips thick fleshy with continuous labial fold across the lower jaw, mouth is small and its gape does not extend below the eyes, snout pointed, jaws of about the same length, two pairs of barbels, maxillary ones slightly longer than rostral ones but shorter than eye, interorbital space flat. Dorsal fin opposite to or slightly in advance of ventral fin, dorsal spine smooth, shorter than body depth, pectoral reaching pelvic as long as

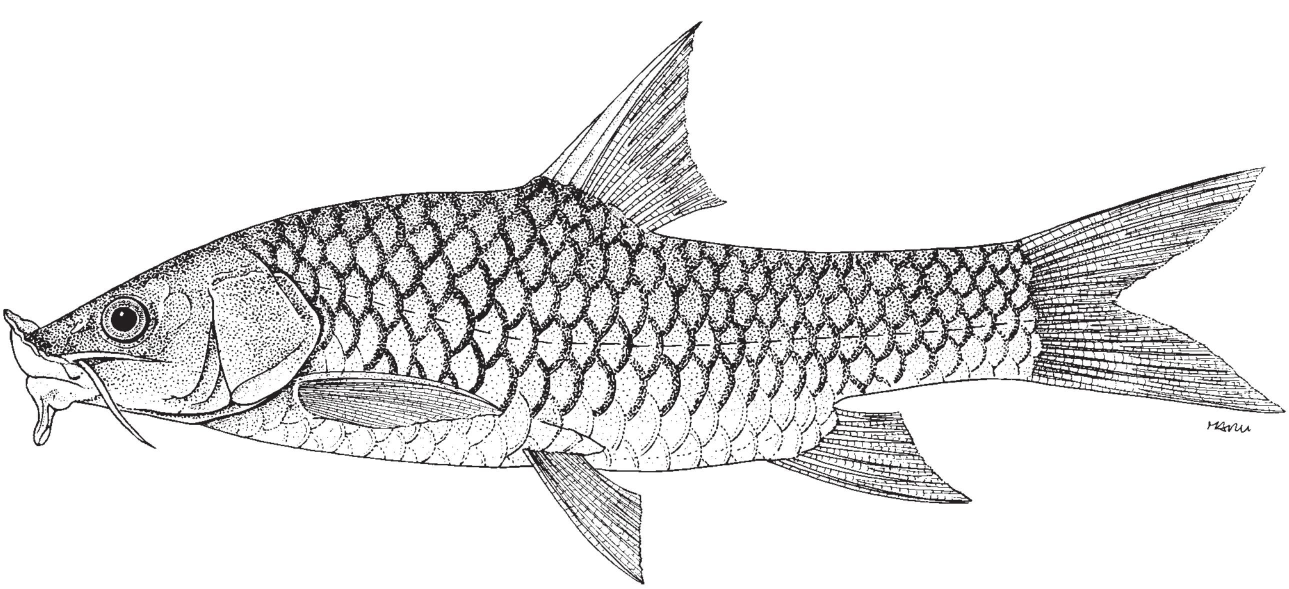


Figure 1. ***Tor tor*** (Hamilton)

head excluding snout, pelvic shorter and when laid flat not reaching caudal-fin base, caudal deeply forked; lateral line complete. Predorsal scales 9. There is a well-developed scaly appendage in the axil of each pelvic fin.

Measurements: Length of head 4, depth of body 3.0 to 3.7 times in standard length. Eye diameter contained 3.0 to 4.0 times in interorbital distance. Least height of caudal peduncle contained 1.2 to 1.4 times in its length.

Coloration: Silvery green or greyish green dorsally, with pinkish sides replaced by greenish gold above and light olive green below, lower fin reddish yellow.

Maximum size: 152.0 cm.

1.2.4 General variability (species and subspecies)

Mahseer is a heterogenous group of fish and this composite term includes the following species as reported from different waters.

(A) VALID MAHSEER SPECIES

1. ***Tor putitora*** (Hamilton) - the putitor mahseer or golden or common Himalayan mahseer. In the Himalayas, including Kashmir, Uttar Pradesh, Punjab, Haryana, Darjeeling (West Bengal), Assam, Bhutan, Nepal. Also in Pakistan, Afghanistan and Bangladesh.

2. ***Tor tor*** (Hamilton) - the tor mahseer or the deep-bodied mahseer. All along the Himalayas, particularly fresh waters of Punjab, Haryana, Uttar Pradesh, Bihar, Darjeeling, Assam, Madhya Pradesh. Bhutan, Nepal, Pakistan, Bangladesh, Myanmar, China. In India the rivers Ganga and Narmada are its principal habitats.

3. ***Tor mosal*** (Sykes) - the mosal mahseer or copper mahseer. It is largely a Myanmar species, rarely found in the Himalayan waters. In India, it occurs in rivers in and around Himalayas, Sikkim and Assam (Jhingran, 1975). Mahanadi is its principal river system in India.

4. ***Tor khudree*** (Sykes) - the khudree mahseer or Deccan mahseer. Fresh waters of Orissa, entire Peninsular India and south of the Tapti River. Rare in the rivers Bhima, Krishna, Koyana and Cauvery. Temple sanctuaries at Dehu and Alandi on the Indrayani River and in some reservoirs.

5. ***Tor mussullah*** (Sykes) - the mussullah mahseer. Fresh waters of Peninsular India. The Krishna and Godavari rivers are its principal habitats.

6. ***Tor progeneius*** (McClelland) - the jungha of the Assamese. North-eastern Himalayas in Assam, Naga-Hills and Manipur.

7. ***Tor douronensis*** (Valenciennes) - Malaysia (North Borneo) (Inger and Chin, 1962; Anon., 1997)

8. ***Tor sinensis*** (Wu) - China, Thailand, Cambodia (Petr, personal communication).

9. ***Tor tambroides*** (Bleeker) - Trey kahor, Thai mahseer. Thailand, Indonesia, Cambodia, Malaysia (Mohsin and Ambak, 1983; Roberts, 1989; Rainboth, 1996).

10. ***Tor zhobensis*** (Mirza) - Reported by Mirza (1967) for the Zhob River in Pakistan. Common and valuable game fish.

(B) VALID SUBSPECIES OF *TOR*

1. ***Tor khudree longispinis*** (Günther) - Most common in hill streams of Sri Lanka and regarded as good game fish.

2. ***Tor khudree malabaricus*** (Jerdon) - Malabar carp. South Kanara down the Western Ghats to Travancore hills.

3. ***Tor mosal mahanadicus*** (David) - Mahanadi River near Hirakud, Orissa. Not yet known from any other river system, even in Orissa.

According to A.G.K. Menon (1992), this subspecies will most probably be ***T. khudree mahanadicus*** and not ***T. mosal mahanadicus*** as described by David (1953a). Further study is needed.

(C) UNCERTAIN SPECIES OF MAHSEER

1. ***Barbus hexastichus*** McClelland: it has some similarities with ***T. tor*** but it is not a ***Tor*** species. Present in the rivers of the Himalayas, in Kashmir, Assam and Sikkim.

2. ***Barbus dukai*** Day: confused with mahseer due to its large scales, colour, large size, and sporting nature. Found in the Tista River in the Darjeeling District of West Bengal and in foothills of Terai and Duars.

3. ***Barbus neilli*** Day: large scales, size and body shape make it similar to ***Tor***. It is closely related to ***Tor khudree*** but it is neither synonymized nor treated as a separate ***Tor*** species due to some confusion which requires further examination. First recorded by Day (1878) from the Tungabhadra River. A Peninsular species.

4. ***Barbus chilinoides*** McClelland: it has some ***Tor*** characters but in other features it is different.

Another large-scaled fish of Nepal and the eastern Himalayan range is 'katli' or 'boker' of Assam, or 'katle' in Nepal (***Acrossocheilus hexagonolepis*** McClld.). It is also called chocolate or red mahseer. It is a separate genus.

Misra (1959) has recognized 4 species of mahseers: ***A. hexagonolepis***, ***T. khudree***, ***T. putitora*** and ***T. tor***. Menon (1974) has recognized the last two species in the Himalayas.

1.2.5 Key to the Indian and Sri Lankan species of genus *Tor* (after Sen and Jayaram, 1982)

1a. Head length more than 5 in total length . . → 2

1b. Head length less than 5 in total length . . → 3

2a. Eye diameter 3.2-4.2 in head length, L.l. scales 23-26, length of head equals depth of body . . . . → ***T. mosal*** (Ham.)

D.4/8-9;P.17;V.8-9;A.3/5;C.19;L.l.23-26;L.tr.3½/3½

2b. Eye diameter 4.5-7 in head length, L.l. scales 25-27, head length more than depth of body . → ***T. mosal mahanadicus*** David

D.4/9;P.17;V.8-9;A.3/5;C.19;L.l.25-27;L.tr.3½/3½

3a. Head length greater than depth of body, dorsal spine smooth and strongly developed, snout not tuberculated, L.l. scales 25-28, length of head 4-4.5 in total length, thick lips. . → Τ. πυτιτορα (Ηαμ.)

D.3/9;P.19;V.9;A.2-3/5;L.l.25-28;L.tr.3½/3½

3b. Head length not greater than depth of body, dorsal spine may or may not be strongly developed, snout may or may not be tuberculated . . . . → 4

4a. Length of head equal to depth of body, L.l. scales 25-27. → 8

4b. Length of head shorter than depth of body . . . → 5

5a. Eye diameter 3-4 in head length, snout not tuberculated, L.l. scales 22-27 . . . . → ***T. tor*** (Ham.)

D.12(3/9);P.19;V.9;A.7-8(2-3/5);C.19;L.l.22-27;L.tr.4½/ 2½

5b. Eye diameter about 6 in head length (more than 4), snout may or may not be tuberculated, length of head 4.6 in total length . . . . → 6

6a. L.l. scales 26-27, pre-dorsal scales 10, eye diameter about 6 in head length, snout tuberculated, length of head less than depth of body . . → ***T. mussulah*** (Sykes)

D.4/9;A.3/5;P.16;V.9;C.19;L.l.26-27;L.tr.4½/3½

6b. L.l. scales 23-25, pre-dorsal scales 10 . . → 7

7a. Head length 4.5-4.7 in total length, pre-dorsal scales 8-9, L.l. scales 23-24, males smaller than females, male with large labial flap . . . . → ***T. khudree longispinnis*** (Günther)

D.4/9; A.3/5; P.1/15-17;L.l.23-24;L.tr.3½/2½

7b. Head length 4.7-5 in total length, rostral barbels short, not extending to eye, L.l. scales 24, eye-diameter 5 in head length, upper jaw longer, thick lips . . . . → ***T. khudree malabaricus*** (Jerdon)

D.12-13(3-4/9);P.17;V.9;A.8(3/5);C.19;L.l.24;L.tr.4/4

8a. A black streak behind gill opening, tip of snout fleshy and formed into a semicircular flap, L.l. scales 26, length of head almost equal to depth of body, dorsal spine less developed, long compressed head, fins shorter . . . . → ***T. progeneius*** (McCll.)

D.12; P.16; V.9; A.7; C.19; L.l.26; L.tr.3/3

8b. No black streak behind gill opening; tip of snout not fleshy tuberculated, L.l. scales 25-27, length of head equal to depth of body, eye diameter 5.5-7 in head length . . . . → ***T. khudree*** (Sykes)

D.4/9; P.15; V.10; A.8; C.19; L.l. 25-27; L.tr. 4½/3½

The generic concept and true specific status of mahseers were in confusion for many years until Hora attempted to classify them in a series of articles (Hora, 1939-1943). Thomas (1873) commented that there are more mahseers than have been named. This is still valid today. To sort things out, it is necessary to collect specimens of different forms to decide which differences are only accidents of local colouring or seasonal changes and which are indicative of varieties and species. Specimens need to include different age groups and be collected from many rivers and localities, in various seasons and in sufficient numbers.

1.3 Morphology

1.3.1 External morphology

Meristic counts of tor mahseer, as described by various authors, are presented in **Table 2**. Twenty characters of ***T. tor*** (TL: 188-815 mm) from the Narmada River were statistically analyzed by Desai

Table 2. Meristic counts of ***Tor Tor***

B	D	P	V	A	C	L.I.	Ltr	Barbels	Authors
3	3/9	19	9	2-3/5	19	25-27	4/4	Two pairs	Day (1878, 1889)
-	4/8	15-18	9	3/5	19	22-27	4½/2½	"	Hora (1941)
-	4/8	15-18	9	3/5	19	22-27	4½/2½	"	Misra (1959)
-	3/9	17	9	2/5	-	25	4½/4½	"	Shrivastava (1980)
-	3/9	19	9	2-3/5	19	25-28	3½/2½	"	Sen and Jayaram (1982)

Table 3. Relationship between total length and body measurements of ***Tor tor*** (Ham.) from River Narmada (Desai, 1982)

S. No	Parameters	Co-efficient of correlation (r)	Formulae
1	Fork Length	0.91	Y = 0.89 x - 7.08
2	Standard Length	0.99	Y = 0.82 x - 9.65
3	Length of head	0.97	Y = 0.22 x - 7.55
4	Height of head	0.99	Y = 0.16 x - 5.84
5	Width of head	0.95	Y = 0.13 x - 8.43
6	Inter-orbital space	0.99	Y = 0.08 x - 3.86
7	Length of snout	0.99	Y = 0.08 x - 4.33
8	Eye diameter	0.93	Y = 0.02 x + 5.31
9	Depth of body	0.96	Y = 0.24 x - 6.89
10	Width of body	0.99	Y = 0.16 x - 10.25
11	Length of dorsal fin	0.99	Y = 0.11 x + 18.31
12	Length of pectoral fin	0.99	Y = 0.14 x + 3.07
13	Length of pelvic fin	0.99	Y = 0.11 x + 5.21
14	Length of anal fin	0.99	Y = 0.15 x - 0.18
15	Length of caudal peduncle	0.99	Y = 0.15 x + 3.42
16	Least height of caudal peduncle	0.99	Y = 0.09 x - 0.37
17	Distance between snout and dorsal	0.99	Y = 0.45 x - 14.21
18	Distance between dorsal and caudal	0.99	Y = 0.46 x - 9.89
19	Length of rostral barbel	0.99	Y = 0.05 x + 0.06
20	Length of maxillary barbel	0.98	Y = 0.05 x + 1.36

(1982) to determine the relationship of each of them (Y) to the total length of fish (X). The formulae expressing the various relationships and the values of coefficient of correlation (r) are given in **Table 3**. Dubey and Dubey (1986-87), using fish from the Narmada River, found that growth of head length in relation to total length of fish was fastest, that of caudal peduncle was the slowest. They also studied the relation of body weight to surface area of fish (K), using the formula S = KW2/3 (where S = area of body surface; W = body weight; and K = a constant). Value of 'K' was 0.537, which is lower on rotund fishes than depressed ones.

Condition of lips varied considerably in different specimens irrespective of size and sex (Desai, 1982). Some had normal lips without pendulous lobes but some had enlarged lips reflected backwards produced into broad lobes (**Figure 2**). Such variation in lips has also been reported by Hora (1936, 1940). While Hora (1936) noticed greatest development of lips in a specimen (TL 485 mm) from the Barak River (Assam), Annandale (1919) described thick and fleshy lips in the largest specimens from Gauhati (River Brahmaputra). Thomas (1897) also observed formation of lips in small immature mahseer and he ruled out the universal opinion of Indian fishermen that mahseer with hypertrophied lips are females.

1.3.2 Pharyngeal teeth

Like all cyprinids, tor mahseer is devoid of any teeth in the jaws but this loss is compensated by the remarkable development of the fifth branchial arch, the pharyngeal teeth. These teeth lie in the throat of the fish and are not used in catching or holding the prey but are employed for tearing and masticating purposes. These teeth occur in three rows (5, 3, 2) on either side (**Figure 3**), the upper consisting of two small teeth, the middle of three and the

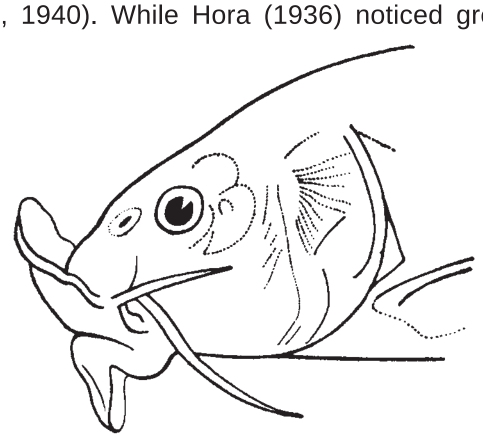


Figure 2. Head of ***Tor tor*** showing enlarged and backwardly lips with pendulous lobes

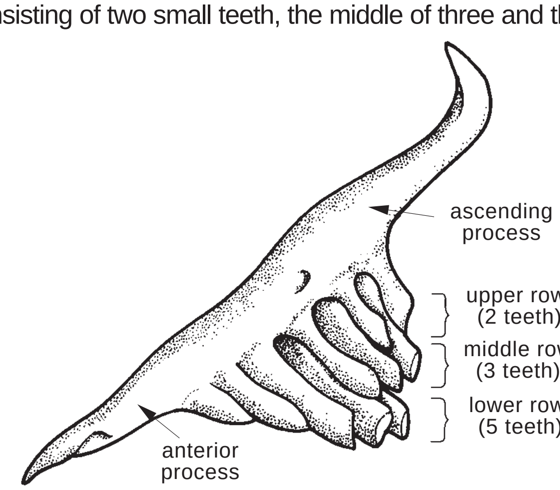


Figure 3. Pharyngeal bone of ***Tor tor*** showing arrangement of teeth

lower having five bigger teeth. The teeth are curved near their extremity and are hooked and pointed. They are not set in sockets like human teeth but are continuations of the pharyngeal bones having a coating of enamel down to their base. According to Hora (1940), anglers in India often preserve the pharyngeal teeth of mahseers as trophies since they provide a reliable evidence of the size of the specimen.

1.3.3 Hypobranchial skeleton

The hypobranchial skeleton of ***T. tor*** from Garhwal region (Uttar Pradesh) has been studied by Nautiyal *et al.* (1980).

1.3.4 Adrenal gland

Sultan and Qureshi (1981) studied the histo-architecture of the adrenal gland of ***T. tor***.

2. DISTRIBUTION

2.1 Total area

In India ***Tor tor*** was originally described from the north-eastern parts of Bengal, but it is now known to be widely distributed. According to Sehgal (1971), in India this species occurs from Jammu in the west to the Brahmaputra Valley in the east all along the Himalayan ranges. Hora (1940) examined specimens from the Brahmaputra and Barak rivers in Assam, Bilaspur (Madhya Pradesh) and from Naga hills. McDonald (1948) noted that besides the snow-fed Himalayan rivers, the rivers having their sources in the Western Ghats of India and in the highlands of central India also have mahseer. Misra (1959) stated that this fish is distributed in fresh waters of East Punjab, Uttar Pradesh, western and eastern Himalayas, Bihar, Darjeeling District of West Bengal, Assam and Madhya Pradesh. Lal and Chatterjee (1962) found this species widely distributed in all the principal rivers of Eastern Doon. Hora (1949) and Motwani and David (1957) reported this species from the Rihand and Sone rivers. Karamchandani *et al.* (1967) recorded it from the Narmada River at Hoshangabad (Madhya Pradesh). The fish fauna of Jabalpur also included ***T. tor*** (Malviya, 1961). It is present in the Tapti River (Karamchandani and Pisolkar, 1967) and it is fished in Ukai Reservoir (state Gujarat, situated on the same river; Menon, 1973). The Mahi River and its reservoir also hold this species. Tor mahseer is reported from the Chambal River (Dubey and Mehra, 1959) and it is regularly fished in Gandhi Sagar Reservoir in Madhya Pradesh (Anon., 1968) and in Rana Pratap Sagar Reservoir in Rajasthan (Chaudhary, 1978). Motwani and Saigal (1974) reported it from Sarda Sagar Reservoir in Pilibhit (Uttar Pradesh). It is also present in Garhwal region of the central Himalaya (Badola, 1975), and in Gumti Reservoir in the state of Tripura (Lipton, 1983-84).

Figure 4 shows the geographical distribution of ***Tor tor*** and **Table 4** gives the rivers, lakes and reservoirs from which the species has been reported.

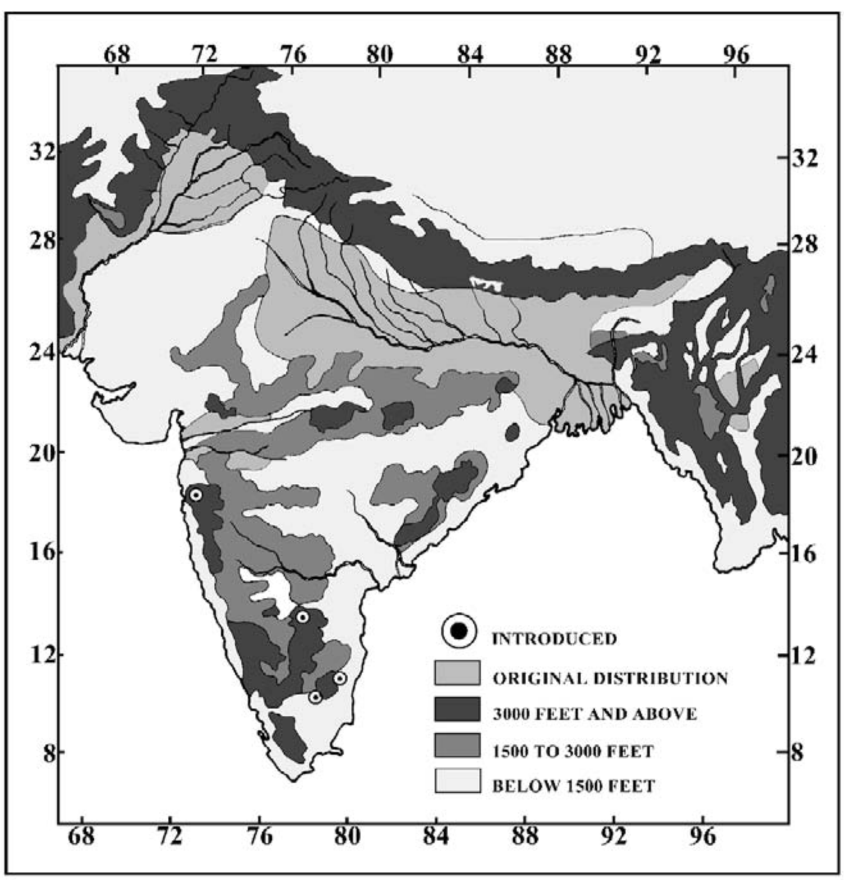


Figure 4. Geographical distribution of ***Tor tor***

Table 4. Distribution in Rivers, Lakes and Reservoirs

India						Myanmar	Bangladesh	Pakistan	China	Bhutan	Nepal
Habitat	Ganga River System	East Coast River System	West Coast River System	Brahmaputra River System	Indus River System						
Rivers and important tributaries	Ganga Yamuna Ghaghra Gomti Rapti Sarda Ramganga Kosi, Sone Rihand Chambal Betwa Ken	Mahanadi	Narmada Tapti Mahi	Brahmaputra Barak	Indus Sutlej Beas	Freshwaters	Freshwaters	Jhelum	Freshwaters	Manas Sarbhang Khola Gaylegphug	Bagmati Kosi Kaligandaki Trisuli
Lakes: Lakes along the foothills of Himalayas in Punjab, Haryana, Uttar Pradesh, Darjeeling district of West Bengal, Assam. Reservoirs: Mangla (Pakistan); Indrasarobar (Nepal); Narmada, Tapti and Chambal Basin (India).											

According to Jhingran and Sehgal (1978), about 1269 km length of streams harbour some species of mahseer. In Jammu and Kashmir there are 378 km, in Himachal Pradesh 681 km, Uttar Pradesh 175 km, Kerala 30 km, and Karnataka 5 km. Little information on the magnitude of mahseer fishery on these streams is available. ***Tor tor*** supports a limited fishery in the Siwalik Himalayas and lower reaches of the uplands of the Deccan Plateau.

<u>Significance of Satpura hypothesis in mahseer distribution</u>

The typical Himalayan ichthyofauna including ***Tor*** originated in southern China and from there dispersed into the Alpine-Himalayan system, ramifying into Europe, western Asia and associated mountains (Hora, 1951). Hora (1951a) opined that during glacial periods the Garo-Rajmahal gap must have been a few hundred metres higher than the sea level and the colder climate favoured increased precipitation with less evaporation and greater runoff in streams like the Narmada - Tapti along the Satpura - Vindhya. These conditions favoured the spread of torrential fishes from the region of the Assam Himalayas to Peninsular India across the Garo-Rajmahal Bridge. According to David (1963), considerable evidence is available on the zoogeographical affinities of various genera of fish found in Peninsular India to support the 'Satpura hypothesis' advanced by Hora to account for the striking similarity in fish fauna of the Malay Archipelago with that of Peninsular India. In 1937 Hora (1937), while referring to the distribution of Himalayan fishes, also explained the occurrence of similar forms in the eastern Himalayas and the Assam Hills on the one hand and the south-western hills of peninsular India on the other by suggesting that the Satpura Mountains probably stretched across India as a continuous range from the Assam Himalayas to Gujarat from the Miocene period until comparatively recent times. The presence of ***T. tor*** in the Narmada River indicates that the Satpura Range served as a highway for the dispersal of eastern Himalayan and Assam forms to the Western Ghats.

2.2 Differential distribution

2.2.1 Spawn, larvae and juveniles

The spawning behaviour of cold-water fish species differs widely from that of their counterparts in warm waters (Jhingran and Sehgal, 1978). The primary requirement for a cold-water fish to lay eggs is gravel substratum where the eggs can be safely covered by the gravel and thus saved from being washed away by strong current. McDonald (1948) observed mahseers migrating considerable distances upstream for feeding and spawning. There they laid eggs in sheltered rock pools. Desai (1973) collected the larval stage of ***T. tor*** together with hatchlings, larvae and fry of other carps from the rocky bed of the Narmada River from July to March. The advanced stages of fry and juveniles of ***Tor tor*** from the Narmada River were also collected by Desai and Karamchandani (1967) along with those of minnow carps ***Barilius bendelisis, B. barila*** and ***Oxygaster clupeoides***. This association seems to suggest that the fry and juveniles of mahseer and minnow carps share the same grazing grounds, i.e. rocks, stones and sand layers covered with algae and other coatings. David (1953) also found the fry of mahseer associated with minnow carps ***B. bendelisis, B. barila*** and ***Aspidoparia morar*** in the Mahanadi River.

2.2.2 Adults

Rivers and streams fed by perennial snow-melt water with shallow beds covered by rocks and stones, and a low water temperature are favourable for mahseers. Mahseer enters side streams or torrential stretches of a river for spawning and returns to the main stream when the water begins to subside. According to Karamchandani (1972), the river stretches must have rapids, pools and rocks. Where the river leaves the last hills, big pools form and the stream spreads into a number of channels. Such an environment is suitable for mahseers. Rivers with two or three junctions of spring-fed tributaries are ideal for mahseer.

2.3 Determinants of distribution

Mahseer is found in rivers, lakes and reservoirs. Rivers must rise in the hills and be perennial, with rocks, rapids and deep pools. Day (1889) found such a habitat especially in rocky mountain streams. Occurrence and distribution of mahseer has more to do with the water temperature prevailing in the streams than the altitude. The fish seems to avoid very cold water. It may be because of this that it congregates by the hundreds in the lower reaches of the rivers Jhelum, Chenab, Ravi, Beas and Sutlej during the winter months of December and January. Himalayan mahseer has a high demand for high concentration of dissolved oxygen. It also seeks rocky beds with molluscs and algal coatings which constitute its diet. Jhingran (1975) noted that mahseers migrate upstream and downstream depending on floods

Desai (1982) stated that clarity of water is an important factor as it results in a deeper penetration of light, thus allowing aquatic plants, molluscs and algae to inhabit deeper waters. This enhances the food supply for mahseer. The fish leaves the main stream when it becomes turbid during monsoon and ascends the hillstream in search of clear water for breeding and feeding. Jhingran (1975) mentioned such migration of ***Tor*** species to clear upper waters in the post-monsoon period. ***T. tor*** which existed in the Rihand River prior to its impoundment (Hora, 1949), disappeared after the formation of Rihand Reservoir in Uttar Pradesh (Motwani, 1970). This is believed to be due to the high clay content in the reservoir which reduced the transparency of water.

Adaptations: During their migration to upper reaches of a river mahseers have to leap over obstacles such as rocks and boulders and overcome strong current. Consequently, mahseers have strong power of locomotion and their fins are more osseous and stronger built than those of other cyprinids. McDonald (1948) noted that the fin area of mahseer is greater than the total surface area of the rest of its body. This makes the fish strong and powerful, enabling it to live in rapid current. The fish has a protrusible and suctorial mouth well adapted for bottom feeding. The suctorial mouth not only gives the fish the power of sucking the loose material from the bottom but also helps the fish cling to the substratum so that it does not get washed away by swift current. The enlargement and thickness of lips is not uniformly developed in all specimens. Its development depends on the type of stream in which mahseer lives and the degree of adherence required to live in swift current (Beavan, 1877; Hora, 1940). Thus the hypertrophy of the lips in ***T. tor*** is a character produced by environmental factors. According to Jhingran and Sehgal (1978), very little food is available in hill streams and therefore cold-water fish species have acquired modifications of the mouth suitable for scraping algal coatings and associated invertebrates from submerged rocks and boulders. Pharyngeal teeth are used for tearing and masticating food such as aquatic plants, molluscs and insects. The form of the teeth is generally correlated with the nature of the food (Hora, 1940).

2.4 Hybridization

2.4.1 Hybrids

Hybridization of ***Tor*** species in nature is not known. In fish-farm conditions, a hybrid of ***Tor*** sp. and rohu (***Labeo rohita***) was reported to be produced by the Fish Seed Production Unit of the Maharashtra State Fisheries, Bombay (Maharashtra Times, 1971). Since mahseer is known to be a slow-growing fish, the idea of this experiment was to get the characters of the parent species in the hybrid, namely the faster growth of rohu and the bait-taking habit of mahseer. Although the species of ***Tor*** used for this experiment is not exactly known, its success has definitely paved the way for other such trials. At the Lonavla Fish Farm in Maharashtra, Ogale and Kulkarni (1987) produced hybrids of ***T. tor*** and ***T. khudree*** and succeeded in breeding the pond-raised hybrids.

2.4.2 Natural hybridization *

3. BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality

Females discharge enormous numbers of eggs and males milt in shoals during spawning and the discharged eggs are fertilized externally. Hermaphroditism is not known in this species.

Sexual dimorphism is indicated by the presence of tubercles on the snout of mature males (Desai, 1973). Mirza (1967) observed that in Pakistan male ***Tor tor*** had thick lips which developed the labial flap into an elongated triangular point reaching the angle of the mouth. But in the Narmada River the thick lips were seen in both sexes. In males the pectoral extends to the 7th scale below the lateral line, while in females it is shorter, reaching the 5th or 6th scale. In females the bulkiness of the abdomen gives rise to an arched ventral profile and the base of the anal fin does not project out of the profile line, whereas in males the profile is comparatively less arched and the base of anal fin not projecting out of the profile line. No differences in colours of the two sexes and roughness of the pectoral were noticed even in ripe males. However, sex identification is only possible when ripe females show a fully bulged and soft abdomen with a slightly swollen pinkish vent. When the abdomen is slightly pressed the mature females and males will discharge eggs and milt respectively.

The differences between the male and female ***Tor tor*** (Kumaun mahseer) from Bhimtal and Naukuchiatal (Uttar Pradesh) recorded by Pathani (1978a) were as follows:

Colour: Colour did not appear to distinguish the sexes. Some males were brighter than females and some males had small black spots on the lateral sides of mouth. These characters, however, were not consistent.

Size: The males were smaller and lighter than the females of identical age. The males were narrower than the females. The head length and body width ratio in the male was higher than in the female during the breeding season.

Fins: The pectoral fins in the males were longer and rough and reached up to the sixth scale of the lateral line. In the females the pectoral fins reached below the fifth scale of the lateral line only and were smooth. The anal fin of the males was thinner, transparent and large with light orange tinge at the tip, in the females of about the same age it was thicker, opaque and smaller.

Tubercles: Tubercles were present on the dorsal side in the head region of the males and were absent in the females.

The nature of lips as described by Hora (1939, 1940) is an ecological adaptation and is very variable and unreliable for sex differentiation. The colour differentiation was hardly a factor for sex recognition although it is a good character for species recognition. The above secondary sexual differences were observed in Kumaun mahseer during the breeding season from April to September.

3.1.2 Maturity

In ***T. tor*** of the Narmada River, 5% of fish are mature at 280 mm TL, 50% at 360 mm, 90% at 440 mm and all the fish are mature when over 500 mm (Desai, 1973). Female fish attained first maturity (50% mature ovaries) in the size range of 340-380 mm. In Lake Udaipur in Rajasthan, the smallest male matured at 254 mm and all females above 310 mm were mature (Chaturvedi, 1976). In the Narmada River, males matured at 250 mm (175 g) in the second year, and females at 360 mm (500 g) in the third year. In Lake Bhimtal this species attained maturity in the size range of 280-350 mm (Pathani and Das, 1983). The smallest ripe male was 202 mm TL (age group 2+), the smallest ripe female was 289 mm TL (age group 3+) (Pathani, 1983).

3.1.3 Mating

Sen and Jayaram (1982) wondered why nobody has ever seen mahseer in the act of spawning. When rivers are low and clear it should not be difficult to observe them. Also egg-laying and fertilization have never been seen, only the embracing act of ***Tor khudree***, similar to that of rohu, but in transparent water below the surface, was described by Kulkarni (1971). The breeding mechanism in mahseers varies from species to species depending on the local ecological factors. Pathani (1983) observed a long process of courtship of ***T. tor*** in Lake Bhimtal, where two to seven males were chasing a female.

3.1.4 Fertilization

Fertilization is external.

3.1.5 Gonads

The gonads occur as a pair of elongated light coloured strap-shaped bodies lying one on each side of the intestine and lodged into the groove between the bladder and abdomen. The mature ovary is a quill-like bag containing large, orange-coloured eggs, measuring from 1.90 to 2.22 mm in diameter. The mature testis is full of oozing milt. The fully mature ovary occupies nearly the whole of the body cavity when the alimentary canal is very much reduced due to poor feeding. Both lobes of the mature ovary are generally equal in length, though in some specimens they are unequal.

Fecundity of ***T. tor*** from the Narmada River varied from 7 000 to 101 600 in fish of 283-750 mm TL. This range was associated with three spawning bursts as the fourth batch of maturing ova (smaller than 0.95 mm) could not be counted (Desai, 1973). By adding the estimated number of ova of the fourth burst, the total number of eggs to be laid in one season was estimated to range from 9 330 to 135 470 (see **Table 5**). The relationship between fecundity (F) and length of fish (L) was:

$$\text{Log } F = 1.9749 \text{ Log } L - 1.0384$$

Table 5. Fecundity of ***Tor tor*** (in thousands) from River Narmada (Desai, 1973)

Total length of fish (mm)	No. of ova laid in three bursts	Probable No. of ova maturing in one spawning season
283	7 000	9 300
322	9 800	13 000
377	8 700	11 600
388	8 240	10 990
388	9 200	12 270
390	12 680	16 900
405	16 750	22 330
422	17 550	23 400
453	15 100	20 130
460	17 800	23 730
460	15 000	20 000
465	28 400	37 860
510	28 300	37 730
552	30 400	40 530
582	31 340	41 790
598	53 800	71 730
657	42 600	56 000
727	54 300	72 400
750	101 600	135 470

The above relationship has shown that with increase in size of fish the fecundity also increases, but less than in other popular carps of India. See also **Table 6**.

Table 6. Calculated fecundity of ***Tor tor*** from River Narmada for different year classes (Desai, 1982)

Age (years)	Fecundity (in thousands)
II	6.6
III	10.3
IV	14.5
V	18.8
VI	22.6
VII	25.5

The average fecundity of ***T. tor*** (465-740 mm in TL) from Lake Udaipur (Rajasthan) ranged from 49 146 to 175 886 eggs. The number of eggs per gramme of the ovary ranged from 256 to 361, and the number of eggs per gramme body weight fluctuated between 24.61 and 36.35 (Chaturvedi, 1976).

The results of microscopic and macroscopic studies of the gonads (ovaries) of ***Tor tor*** from the Narmada River follow:

<u>Microscopic study</u>

Study of ova diameter in different months has shown that the fish has a prolonged breeding. The state of maturity varies greatly among individuals in different months. Thus, in a particular month, fishes in all stages of maturity were encountered. The ovaries were classified into 13 stages of maturity (**Figure 5**)

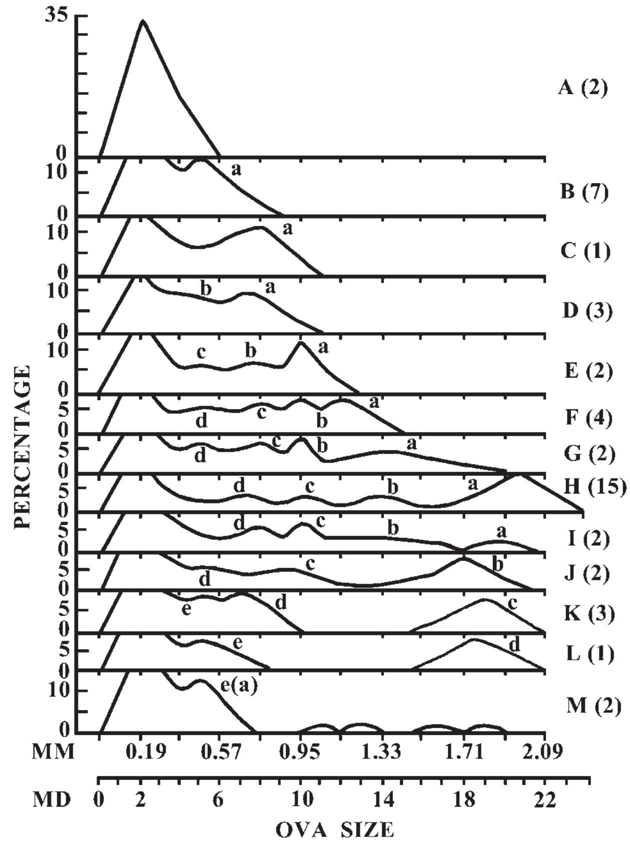


Figure 5. Ova diameter frequency polygons of different maturity stages of ***Tor tor***

and each stage has been compared with the stages of I.C.E.S. (Wood, 1930) (**Table 7**).

The observation clearly showed that ***T. tor*** in the Narmada River exhibits a continuous process of maturation and the ovary starts maturing as soon as the last batch of ova is laid.

Table 7. Maturity scale of ***Tor tor*** (female) (Desai, 1973)

ICES (Wood, 1930)		*Tor tor*
Immature (Stage A)	I	Ovary slender, thin, short, whitish and ribbon-like, ova minute, transparent and not visible to naked eye, some devoid of yolk deposition while in some yolk deposition just commenced; frequencies with one mode, maximum ovum diameter = 0.57 mm; common all the year round.
Maturing (Stage B)	II	Ovary slightly enlarged and becoming translucent; yolk deposition further progresses and ova become yolky, opaque and visible to naked eye; frequencies with two modes, maximum ovum diameter = 0.76 mm; common from December to April.
Maturing (Stage C, D, E, & F)	III	Ovary turns yellow and becomes thickened on all sides, ova have granular appearance and are visible to naked eye; frequencies with two to five modes, maximum ovum diameter = 1.33 mm; common from December to April.
Mature (Stage G)	IV	Ovary greatly enlarged with large mature eggs still contained within the ovarian follicle and not free; frequencies with five modes, maximum ovum diameter = 1.90 mm; common from April to June.
Mature (Stage H)	V	Ovary appears like a yellow bag of cellophane paper containing large, yellow, free and mature ova; frequencies with five modes, maximum ovum diameter = 2.28 mm; common from June to September.
Partly spent (Stage I, J, K & L)	VI	Ovary reduced in size posteriorly, slightly bloodshot and flaccid owing to expulsion of some mature eggs, few mature eggs still present for subsequent spawning frequencies. initially with five modes but subsequently with three modes; common from August to October.
Spent (Stage M)	VII	Ovaries become flabby, further contracted, appear like a wrinkled, collapsed sacs with leathery wall in contrast to the parchment-like wall of distended ripe ovary; frequencies with two modes, sometimes showing insignificant modes of mature and degenerating ova; common from October to November.

With a view to elucidate the breeding season, Desai (1973) also noted the monthly averages of mean diameter of 25 large-sized ova. The ova diameter increased progressively from April (0.519 mm) to September (1.253 mm) and thereafter decreased gradually until March (0.435 mm). High values of mean ova diameter from July to September indicated peak breeding during this period.

Macroscopic study

The maturation of ovaries was followed by calculating gonadosomatic index (GSI). The GSI of females progressively increased from March (2.85) to August (30.10) and declined in September (25.44), indicating the commencement of breeding in July-August. The GSI gradually decreased from October (6.56) to February (4.17) giving indication of continuity of breeding until February-March. The GSI of male fish also showed peak values in July-August (Desai, 1973).

The gross examination of gonads of females, mostly maturing (92.7 percent) in April-June, mature or ripe (57.7 percent) from July to September, and partly spent and resting (93.1 percent) from October to March, also confirmed the prolonged breeding season commencing in July-August and continuing until February-March with the peak from July to September.

Chaturvedi (1976) inferred from monthly changes in the gonads of ***T. tor*** from Lake Udaipur in Rajasthan that fish breed there only once a year from July to September, with peak in August. Pathani (1983) recorded four groups of eggs in ripe females from Lake Bhimtal, with breeding from April to September intermittently in four acts in a season.

3.1.6 Spawning

The multiplicity of modes in ova-diameter frequency of maturing and ripe ovaries of ***Tor tor*** from the Narmada River (Desai, 1973) suggested that individual fish spawn more than once in each spawning season. The stock of small eggs, which was not sharply separated from the maturing eggs, indicated continuous and prolonged process of spawning. This was also supported by the longer occurrence of ripe ovaries of Stage H and partly spent females, extending from July to February. The ova-diameter study of Stage H revealed a distribution of maturing and mature eggs represented by four modes, far apart from one another. The presence of maturing ovaries (Stage G) in November suggested that the breeding extends until January-February. Thus, the individual fish exhibit protracted spawning in 3-4 acts, probably with an interval of 2-3 weeks, and the differential spawning of the entire population shows a prolonged spawning period (Karamchandani *et al*., 1967). In Lake Udaipur in Rajasthan, Chaturvedi (1976) observed that the intra-ovarian eggs of this fish fell into two distinct groups with no evidence of secondary modes and concluded that the fish spawns once a year during a short period. This observation differed from those of many others.

Desai (1973) also studied the length-frequency distribution of hatchlings, post-larvae and fry (size range: 6-60 mm) collected from the Narmada River during July to April. The monthly analysis of these data endorsed the idea of prolonged spawning of the species (**Figure 6**). Hora (1940), on the basis of collection of a large number of young specimens, concluded that the fish breeds during August-September. Hora and Nair (1944) collected very small fry of ***Tor tor*** in March-April from side pools of the lower section of the Riyang - a stream in the Darjeeling Himalayas.

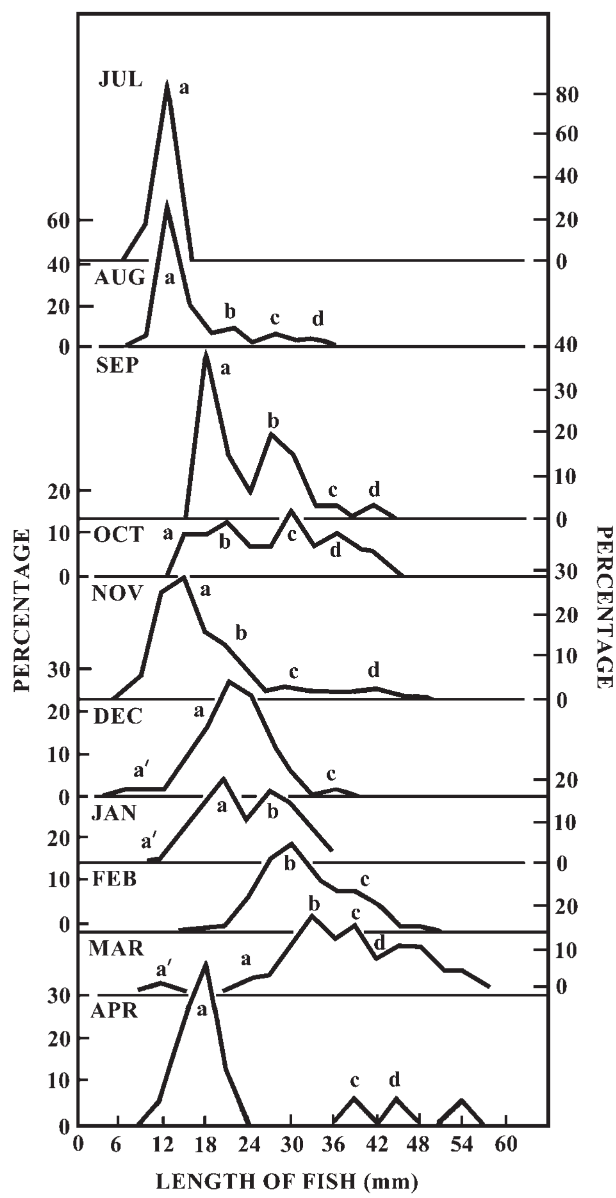


Figure 6. Length-frequency of hatchlings, post-larvae and juveniles of ***Tor tor*** showing spawning frequency

The observations recorded by others (Day, 1873; Beavan, 1877; Dunsford, 1911; Nevill, 1915; Dhu, 1918) pertain to the breeding of mahseer in general. They were of the opinion that mahseers bred several times in a year including the monsoon months. On the basis of migration of mature fish, Codrington (1946) indicated two breeding seasons of mahseer - a minor breeding season in January-February and a major breeding in August. Beavan (1877) says, "The mahseers are said not to deposit their spawn all at once like the salmon, but in small batches during a period of several months, say from May to August." Thomas (1897) remarked that mahseer does not spawn all at once but lays one egg a day for many days like a fowl and repeats this process several times in a season. Khan (1939) disagreed with his view. From the study of sex organs he and McDonald (1948) concluded that mahseer spawns three times a year, i.e. in January-February, May-June and July- September. But their assumption may not be appropriate for the Narmada mahseer which was found to breed intermittently in 3-4 acts laying only part of the eggs at a time, as believed by Thomas (1897). Pathani (1983) located spawning grounds on sandy bottom, pebbles and aquatic weeds at a depth of 2.0 to 2.3 m in Lake Bhimtal.

Some authors consider water temperature as a factor inducing the spawning. During the prolonged breeding of the fish from July to March, the water temperature of the Narmada River ranged from 19.9 to 28.4^{O}C (Desai, 1973). It seemed that optimum conditions for breeding were reached with the lowering of water temperature, as in the snow-melt waters of the Himalayan rivers during hot months or in cooler waters of the Deccan Plateau in winter months. The observations on spawning of fish in Rajasthan (Chaturvedi, 1976) suggested that clear water floods accompanied by drop in temperature are essential for spawning of mahseers. In Lake Bhimtal mahseer spawned in a perennial streamlet entering the lake, with water temperature and dissolved oxygen higher than those in the lake (Pathani, 1983).

Spawning of many freshwater fish takes place in shallows of floodplains. ***Tor tor*** migrates to upper reaches and in streams entering the river when the monsoon showers cause flooding. This helps the fish to reach the shallow breeding grounds. But as seen in ***Tor tor*** of the Narmada River, since the breeding continues even after monsoon until February-March, floods may not be so important for mahseer as they are for the breeding of the major Indo-Gangetic carps. Pathani (1983) collected mahseer eggs and larvae from spawning grounds where ripe fish were present; after breeding these fish returned to deeper parts of the lake, showing no parental care.

The nesting habit, as exhibited by scooping of sand for deposition of ova, has been described by Thomas (1897). This was not observed with the Mahanadi mahseer. David (1953) observed depressions caused by the breeding mahseers in the Kabbani River in Mysore. Each depression which gradually gets exposed as the water goes down, is locally known as 'thippe' in Kannada. It is generally 120-180 cm in diameter, being round or semi-oval in shape and about 0.5 m deep. This habit has been also reported for ***T. tor*** from the Chambal River, off the Gandhi Sagar Reservoir in Madhya Pradesh.

Monsoon floods and physico-chemical factors induce mahseers to ascend their spawning grounds and stimulate them to become sexually active. Internal secretion of pituitary hormones is greatly responsible for ovulation and changes in eggs. The behaviour of mahseer indicates that it is probably the pituitary sex hormone which is directly responsible for ovulation. The histo-physiology of the pituitary gland in conjunction with the ovarian and testicular cycles of ***T. tor*** has been studied by Rai (1966, 1966a).

3.1.7 Spawn

Kulkarni (1980) collected fingerlings of ***Tor tor*** from the Narmada River near Hoshangabad (Madhya Pradesh) in November 1973 and released them into Walwhan Reservoir at Lonavla. There they thrived and attained a total length of 540 mm (1.75 kg) by July 1978. ***T. tor*** was bred in the associated fish farm using stripping, as was done regularly at the same farm with ***T. khudree***. On 23 August 1978 a ripe female of 540 mm TL was caught and stripped. It yielded a first batch of 6 000 eggs, which were cross-fertilized with milt of ***T. khudree***. The second effort, after half an hour, yielded 400 ripe eggs and these were fertilized with milt of ***T. tor*** which was reared in a pond in the farm. Both batches of eggs produced fry. Dissection of the female yielded another cluster of 10 800 unripe eggs.

Collection of 17 200 eggs from this female partially corroborates the estimate of fecundity made by Desai (1973). Chaturvedi (1976) estimated fecundity of 78 340 ova for a fish of 546 mm total length. In the present case, the first batch of 6 400 ripe eggs was laid during stripping and the remaining ones, which were unripe, were probably intended for the next spawning bursts.

The diameter of the eggs immediately on stripping was 2.3 mm and on fertilization and absorption of water, they reached a diameter of 2.8 mm (Kulkarni, 1980). The colour of the eggs was a pale lemon-yellow. The eggs were demersal and full of yolk. Desai (1973) mentioned size of ovarian eggs of ***T. tor*** as varying from 1.0 to 2.22 mm and orange coloured. The variation in size and colour may be due to the fact that they were 'ovarian', i.e. yet to pass through the final stage of maturation necessary for proper fertilization. The previtelline space in the fertilized eggs is slightly narrower and much smaller than in the case of catla (***Catla catla***), rohu or mrigal (***Cirrhinus mrigala***). Other particulars of the embryonic development of the larva within the capsule are similar to those of ***T. khudree*** (Kulkarni, 1971) and therefore the same account is given here.

The eggs are not soft and smooth like carp eggs but tough and rough to the touch. They resemble trout eggs but are smaller in size and comparatively lighter in weight. **Figure 7a** illustrates a freshly laid egg, heavily yolked and without oil globules. **Figure 7b** shows an egg three hours after fertilization: a cap of protoplasm is gathered at one pole of the egg forming a blastodisc. Fertilized eggs of ***T. tor*** collected by Pathani (1983) from Lake Bhimtal had smaller size (2.16-2.38 mm) and orange colour as compared to larger eggs (2.88-3.02 mm) of ***T. putitora***, with yellow to slight orange colour.

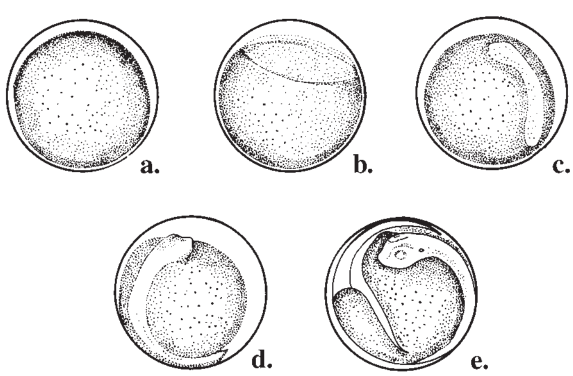
3.2 Pre-adult phase

3.2.1 Embryonic phase

After 24 hours (**Figure 7c**) the embryo develops further and becomes comma-shaped; the cephalic portion can be distinguished but the optic lobes are not clear. The head and the body of the embryo are closely attached to the yolk. There is no visible movement of the embryo.

After 48 hours (**Figure 7d**) the head and the tail portions of the embryo are prolonged and they distinctly raise the surface of the yolk which is now reduced in size. Twitching movements of the embryo are seen but they are slow and occur after an interval of two to three minutes. The movements of this stage are not jerky as in the rohu or catla eggs. Outline of the eyes and the lens are seen but no pigment in the eyes is visible yet.

After about 58 hours (**Figure. 7e**) the body becomes more defined and clearer, and the head is well defined. The sclerotic ring and the lens are seen but are without pigment. Movement of the embryo within the egg has now become more frequent and vigorous than in the previous stage. This movement is so forceful that it makes the egg roll if kept in a flat petrie dish.



Embryonic stages

Figure 7. Eggs of ***Tor tor*** (Kulkarni, 1980) - **a**. newly laid egg; **b**. egg three hours after fertilization; **c**. egg 24 hours after fertilization; **d**. egg 48 hours after fertilization; **e**. egg 58 hours after fertilization

About two hours before hatching the tubular heart of the embryo is pulsating rhythmically; the blood capsules in the vessels are visible but almost colourless. Auditory sacs with otoliths and fully developed eyes are also visible but the latter are without much pigment except minute melanic dots on the peripheral ring. Pectoral-fin buds are discernible. Of the total lot of fertilized eggs, the first egg hatched in 76 hours, but the remaining eggs started hatching after 79 to 85 hours, with a few hatching the next day. If the extremes are not taken into account, the average hatching period is 82 hours at water temperature of about 24^{O}C. The description of larval phase (from hatchling to adult form) of ***T. tor***, given by Kulkarni (1980a), follows.

3.2.2 Larval phase

Newly hatched larva (**Figure 8a**): It is 9 mm in total length, with a long prominent yolk sac, a protruding head and a thin inconspicuous tail. Eyes have a clear outline but the pigment is not very dark. Rudiment of the mouth can be seen, though the jaws are not clear. The pulsating heart is still visible. The yolk sac, being large and yellow in colour, is quite distinctive and measures 5.7 mm in length. It is bilobed, the anterior one being more rounded than the posterior one which is rather narrow in width and elongated, but both lobes are almost equal in length. The dorsal-fin fold starts slightly anterior to the midpoint of the total length, and continues over the caudal end and terminates near the posterior end of the yolk sac at the expected position of the anal opening. The pectoral fin is small and seen fluttering but no fin rays are discernible in it. The myotomes and some blood vessels are clearly seen. The larva manifests the behaviour of remaining quiescent and lying on its side at the bottom of the hatching tray. It exhibits jerky movements intermittently and vibrates its tail when slightly disturbed.

Two-day-old hatchling (**Figure 8b**): Total length attained is 10 mm. Although the increase in length was nominal, the larva looked much fatter and stouter and continued to remain quiescent, lying on its side

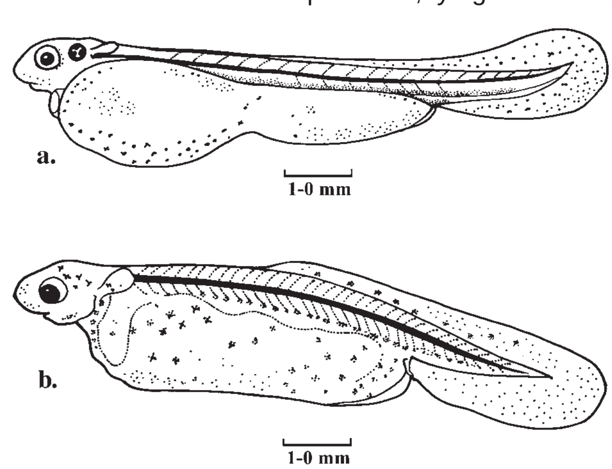
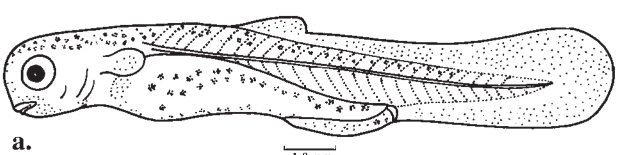


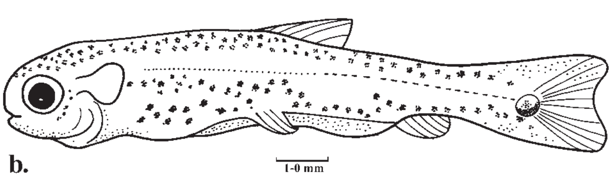
Figure 8. Hatchlings of ***Tor tor*** (Kulkarni, 1980) **a**. one day old; **b**. two days old

and moving vigorously at intervals. The eyes have now become distinctly black with a golden ring when seen in reflected light. Large chromatophores are seen on the anterior portion of the otocyst, yolk sac and at the base of the pectoral fin. A row of elongated pigment specks are lined up between the dorsal portion of the body and the yolk sac. These probably mark the position of the future lateral-line scales and are continued in the caudal region. Indented or broken outlines of the upper internal margin of the yolk sac, which is visible, provides a clear indication of the yolk being absorbed within the body. In the mouth area, the lower jaw is developed and is seen twitching at intervals. Gill covers are also seen moving slowly. The anal opening and the anal tube are perceptible. The dorsal fin fold shows a small upward growth indicating the position of the dorsal fin, but no trace of fin rays can be seen either in this fin or the caudal lobe. A small vertical fin fold on the posterior part of the yolk sac is visible, as well as the anal myotomes, which are clearly visible in reflected light in live tissues.

Three-day-old hatchling (**Figure 9a**): After three days, i.e. on the fourth day, the larva attains a length of 11.5 mm. The chromatophores at this stage cover the body and the head. They are small in size but large in number. No fin rays are yet discernible in any of the fin lobes. The yolk sac is still quite prominent but it has changed its outer form by becoming a single continuous sac pointed posteriorly. The fin lobe in the pelvic area, i.e. on the posterior part of the yolk sac, is reduced in size. The larva tries to swim in the normal erect position of a fish but it has still not reached the free swimming stage.



a.



b.

Figure 9. Larvae of ***Tor tor*** (Kulkarni, 1980)
a. three days old; **b**. ten days old

Ten-day-old hatchling (**Figure 9b**): On the eleventh day, the hatchling emerges as a fry of about 12.5 mm in total length. The yolk sac is completely absorbed. While the length has not increased appreciably during the last five days, the development of the external structures has visibly progressed. The body has thickened and the chromatophores have multiplied many times. They are small on the head, gill cover and dorsal side of the body all along the length but large multiradiate chromatophores are seen on the anterior part of the body and below the lateral line. In the caudal region there is a large dark blotch at the base of the caudal fin.

The dorsal fin is clearly demarcated out of the dorsal or the median fin fold, the latter having been completely absorbed up to the caudal lobe where a small vestige remains. In that fin, five rays are seen and the rest are in developing stages. The caudal fin is also demarcated clearly, it is terminal, and what was rounded in the earlier stage is becoming slightly bifid. Thin fin rays have appeared in the central portion. The anal fin is also marked out with its fin rays developing. A portion of the fin fold anterior to the anal opening still persists and in that region a pair of pelvic fins are making their appearance.

Time of first feeding: The fry at this stage starts feeding intensively on small nauplii of *Artemia* and on small *Moina* and starts moving actively in the glass tank.

3.2.3 Adolescent phase

Fifteen-day-old fry: After 15 days, the fry is 13.5 mm in length; while it does not progress noticeably in length it continues to fatten and looks stouter than before. Even the caudal portion, which was thin previously, has become thick and prominent with a caudal blotch on it. The chromatophores are small and thinned out with the result that the fry looks translucent, and there is a development of thin scales. The fry is olive-white in reflected light. The dorsal fin has eight fin rays and the pelvic fin seven. The pectoral-fin rays are developing but only 12 can be counted. The air bladder is also developing. The vertical fin fold is completely absorbed except a small portion anterior to the anal opening.

Desai (1973) described the following five stages of ***T. tor*** from a collection of post-larvae from the Narmada River:

(i) 8.74 mm stage (**Figure 10a**) - This is the smallest stage in the collection. The larva is pale yellow in colour and looks stout because of its big-sized yolk sac. The yolk sac is slightly brownish in colour and is broad anteriorly, gradually tapering to its posterior end. A row of pigmentation is seen on the upper posterior half of the yolk sac. The head is broad with pigmented eyes and anterior mouth. The median fin fold is continuous. The dorsal fin is demarcated but rays are not evident in it. The caudal fin is somewhat truncated in shape. The notochord is slightly upturned. The hypural plates have developed at this stage and 7-8 rudimentary rays are seen in the caudal fin. The anal fin is not yet demarcated. The pelvic fin is not formed. The pectoral fin is seen as a membranous flap without any rays. A total of 39 myotomes are discernible. The vent is situated back towards the caudal portion below the level of the 27th myotome.

(ii) 9.50 mm stage (**Figure 10b**) - In this stage, the yolk sac is slightly reduced. A cluster of chromatophores is visible on the head. The dorsal fin is more clearly demarcated and contains about 7-8 rudimentary rays. A slight depression is seen in caudal fin which comprises 15-16 rays. The anal fin region is slightly demarcated with no indication of rays in it. The pectoral fin is still a membranous flap and rays are not evident in it. About 40 myotomes can be seen in this stage. The air bladder is visible above the yolk sac in between the 8th and the 16th myotomes.

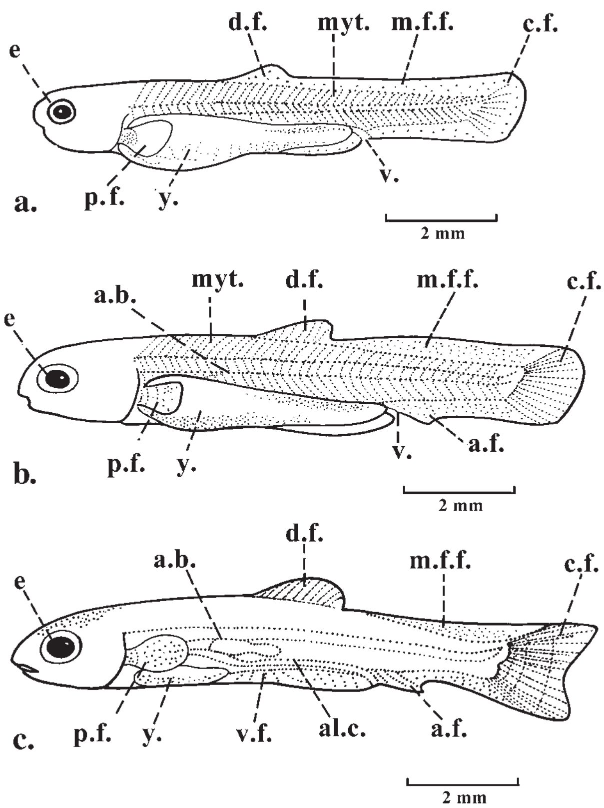


Figure 10. Larval stages of ***Tor tor*** (Desai, 1973) **a**., **b**. and **c**. showing 8.74, 9.50 and 10.70 mm stages respectively

(iii) 10.70 mm stage (**Figure 10c**) - By this stage the yolk is largely consumed, with only a trace left. The anterior part of the body looks stout while the posterior part has become slender in form. The gape of the mouth is now halfway between the tip of the snout and anterior margin of the orbit. The dorsal fin is almost completely formed with all its complement of rays but it is still connected with the caudal fin by a narrow strip of fin fold. The caudal fin is deeply formed and contains 19 rays. Three rudimentary rays are visible in the anal fin. The rudimentary pelvic fin is visible as a minute bud in front of the vent. No rays are evident in the pectoral fin. The alimentary canal has a tubular form. A cluster of chromatophores is present on the head.

(iv) 12.16 mm stage (**Figure 11a**) - The yolk is completely absorbed and the larva more or less resembles the adult fish. The dorsal fin is detached from the dorsal median fold and a trace of the dorsal median fin fold is still visible near the caudal fin. The anal fin contains seven well-developed rays and still retains its connection with the ventral median fold. The pelvic fin is further developed. A trace of pre-anal fin fold is also visible. The pectoral fin is still without rays. A black dense cluster of chromatophores is present on the head, a few scattered chromatophores are also on the snout.

(v) 14.25 mm stage **(Figure 11b**) - The larva has acquired almost all the characters of an adult fish. All the fins are fully formed. The anal fin which now contains 9 rays, is completely separated from the ventral median fin fold. The pelvic fin is well developed and about 9-10 rays are discernible in the pectoral fin. A few scattered chromatophores are seen on the back of the larva. The spot on the caudal peduncle has become more prominent. According to Pathani (1983) this stage was attained after 12 days of rearing of fry since hatching.

The body measurements of the above larval stages are presented in **Table 8**.

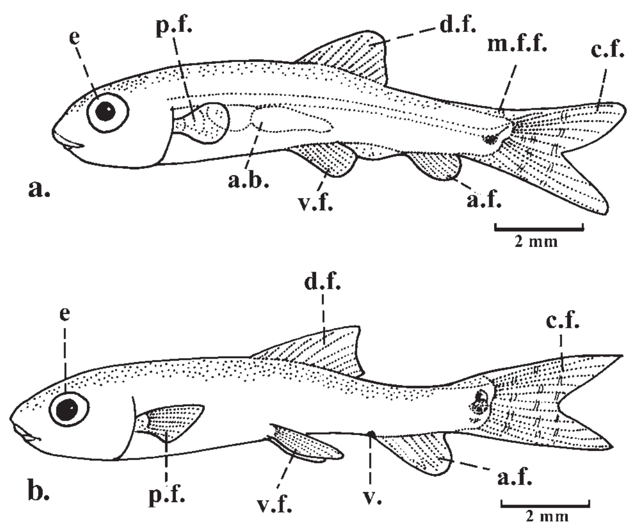


Figure 11. Larval stages of ***Tor tor*** (Desai, 1973) **a.** and **b.** showing 12.16 and 14.25 mm stages respectively

While the smallest stage in the collection made by Desai measured 8.74 mm, the youngest hatchling obtained by Kulkarni was 9.00 mm. While the small difference in the total length is negligible, Desai discerned several external structures, such as demarcation of dorsal fin, the tail becoming forked, a single lobed yolk sac which tapers posteriorly, and appearance of rudimentary caudal-fin rays which Kulkarni did not describe for a 9 mm larva. Desai's description suggests that his larva could have been three days old, the same age as the 11.5 mm larva in Kulkarni's observations. But Desai's 10.7 mm fry was much more advanced than the 11.5 mm post-larva described by Kulkarni. Both larvae had 40 myotomes. As opined by Kulkarni (1980), these differences could be explained by the higher stress on larvae in open waters, resulting in smaller larvae there than in protected waters, i.e. in hatchery conditions.

Table 8. Body measurements of larval stages of ***Tor tor*** (Desai, 1973)

Body measurements (mm)	Larval stages				
	I	II	III	IV	V
1. Total length	8.74	9.50	10.74	12.16	14.25
2. Fork length	-	-	10.26	10.93	12.65
3. Standard length	7.79	8.55	9.22	9.69	11.12
4. Distance between snout and vent	5.98	6.36	6.84	7.69	8.27
5. Length of head	1.61	1.90	2.19	2.56	2.95
6. Height of head	1.45	1.63	1.62	1.90	2.10
7. Height of body	-	-	1.62	1.90	2.28
8. Diameter of eye	0.48	0.57	0.67	0.85	0.95

3.3 Adult phase (mature fish)

3.3.1 Longevity

Against the asymptotic length of 875 mm calculated by Desai (1982) for ***T. tor***, a maximum length of 865 mm (approximately 10+ years old fish), has been recorded from the Narmada River at Hoshangabad. Going by the asymptotic length (875 mm), the mean length at maturity (360 mm), the ratio of mean length at maturity and asymptotic length (0.4), and the occurrence of seven age groups in the population of the species from the Narmada River, Desai (1982) concluded that ***Tor tor*** is a long-living species.

3.3.2 Hardiness

Mahseers are both cold-water and warm-water fish. Besides inhabiting hill streams, lakes and reservoirs receiving snow-melt water, they are widely distributed in warm waters of the Peninsular Plateau. Hence, on the basis of temperature tolerance, the genus ***Tor*** is eurythermal. ***Tor tor*** and other mahseers have great powers of locomotion, having broad fins to surmount the swift stream currents during their spawning migrations. Since the hill streams have very little food, mahseers have modified mouths for scraping algal coatings off the rocks and boulders, together with the associated invertebrate fauna.

3.3.3 Competitors

The fry of ***T. tor*** feeds on filamentous algae, insects and diatoms and therefore it does not compete with common carp, Indo-Gangetic major carps and Chinese carps, which feed on plankton. The juveniles of ***Tor tor*** are insectivorous and the adults feed on aquatic macrophytes, filamentous algae, molluscs and insects. Cyprinids, ***Puntius pulchellus***, ***Puntius sarana***, ***Puntius dobsoni***, ***Puntius kolus*** and ***Acrossocheilus hexagonolepis*** are likely to compete with ***Tor tor*** as they more or less share the same food sources.

3.3.4 Predators

The predatory fish ***Wallago attu***, ***Channa marulius***, ***Channa striatus***, ***Notopterus chitala***, ***Silonia silondia*** and ***Mystus*** spp. as well as piscivorous birds and otters may also feed on mahseers.

3.3.5 Parasites, diseases, injuries and abnormalities

Tor tor of the Narmada River was found to be infested by a digenetic trematode ***Isoparorchis*** sp. (Desai, 1982). This infestation was characterized by the occurrence of black nodules or cysts 2-5 mm in diameter, most common in the body cavity. Some cysts were also deeply embedded in the muscles. On opening the cysts metacercariae were found. Often the parasites were found free in the body cavity around the alimentary canal, gonad or other visceral organs.

There was no infection in smaller fish (201-350 mm) of both sexes. It was first observed in the size range 351-400 mm in both sexes. The infection was higher in females. Infected fish ranged in size from 351 to 800 mm, with a higher infection rate in fish of 401-550 mm. Large males (551-800 mm) were free of infection.

Observations on the intensity of infection irrespective of sex have shown that while smaller fish of 201-350 mm had no parasites, the number of parasites increased with increase in fish size. The infection was highest from December to February, lowest in August-September, and moderate in other months.

From the above observations, Desai (1982) concluded that the infection of ***Isoparorchis*** in ***Tor tor*** depended on the feeding habit of the fish. Juveniles of up to 200 mm feed primarily on insects. Beyond 300 mm the diet changes to macrophytes, algae and molluscs. Since molluscs are the intermediate host of trematode parasites and they are a prominent food component in adult fish, the infection first appears in the larger fish.

The seasonal fluctuations in the infection and the low numbers of parasites in August and September seem to be related to the peak breeding of the fish which coincides with a very low feeding intensity. Also, during monsoon when rivers are in flood, the chances of contact between the fish and the intermediate host are reduced due to the benthic molluscs being largely washed away. From October onwards, with reduced water discharges, the infection increases, reaching a peak from December to February, which is the period of greater intake of molluscs.

3.4 Nutrition and growth

3.4.1 Feeding (time, place, manner, season)

The protrusible and suctorial mouth, two pairs of barbels and the presence of large quantities of sand, mud and debris in the guts of ***Tor tor*** are suggestive of marginal bottom-feeding habits. The frequent occurrence of bottom dwellers such as molluscs and insect larvae in the gut contents prove conclusively that the fish is adapted for feeding on the bottom, but it also feeds on macrophytes, which are commonly found in its gut. The bones and large fish scales encountered in the guts of the fish were probably taken accidentally with other bottom food (Desai, 1970). Thomas (1873) observed that mahseer feeds on aquatic plants, crabs, earthworms, insects, shrimps and molluscs, and found that very little food was taken from the water surface. The bottom-feeding habits, suctorial action of the mouth and the ability to rapidly suck up bottom food were also discussed by Thomas (1873).

Tor tor has pharyngeal teeth which are utilized for tearing and masticating food, as seen from the crushed bivalve and gastropod shells in the gut contents (Hora, 1940; McDonald, 1948). Beavan (1877) noted that the thickness of the lips depended on the kind of stream in which mahseer lived, and that the larger specimens had soft thick lips. According to Hora (1940), the enlarged lips are an adaptation for adhesion to the substratum in a swift current.

The low feeding intensity of ***Tor tor*** from June to October in the Narmada River coincided with the peak of breeding. The feeding improved after breeding and peaked in January-February. The feeding activities then declined with the progressive maturation of gonads from March to April. The low feeding activity during the peak of breeding may be attributed to the fully developed ovary, leaving limited space for food. The low feeding intensity of the fish was also correlated with the poor supply of food in the Narmada River when the grazing grounds are damaged or lost during monsoon months on account of floods.

As seen from the correlation between the feeding intensity and condition factor (ponderal index) depicted in **Figure 12**, the condition of fish has a direct correlation with feeding activity. The poor condition of fish from June to October is evidently due to cessation of feeding. The feeding intensity of ***T. tor*** from the Garhwal Himalaya, as reported by Sharma (1986-87), showed two peaks: the first in July during the post-spawning period, the second in December when there was an abundance of phytoplankton. Dasgupta (1990) while working on the same species from the Sinsang River (Garo Hills, Meghalaya), noted that the feeding intensity increased with growing length and showed a positive relationship with the condition factor.

3.4.2 Food

In the Narmada River the food of ***Tor tor*** was dominated by macrophytes (48.5% of the total volume), followed by filamentous algae (14.5%), molluscs (10.5%), insects (8.3%), debris (7.9%), and sand and mud (7.8%). By frequency of occurrence, aquatic macrophytes (57.5%) constituted the main component, followed by molluscs (36.2%), sand and mud (34.6%), insects (32.8%), filamentous algae (25.1%) and debris (14.8%). Piscivorous feeding habit was rarely observed. Food composition studied by the two methods indicated disparity in the gradation of food items other than aquatic macrophytes. An overall picture of the broad groups was therefore obtained by calculation of the 'Index of Preponderance' (Natarajan and Jhingran, 1961) as shown in **Table 9**. It shows that the fish is largely a herbivore, chiefly feeding on aquatic plants and algae, supplemented by molluscs and insects. Occurrence of sand and debris indicates a bottom feeding habit. The length of intestine is 1.5 to 3.2 times the length of fish, and gut length increases with

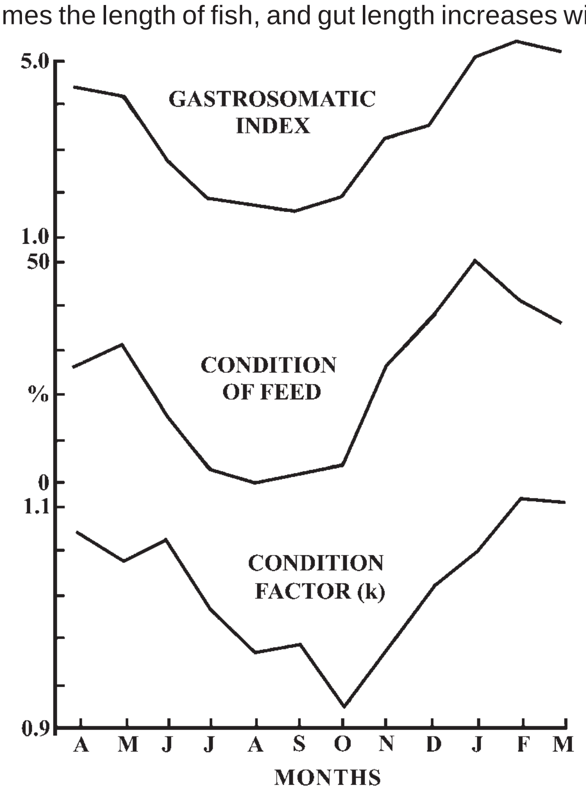


Figure 12. Monthly variations in feeding intensity and condition of ***Tor tor***

the increase in fish length. Lal and Chatterjee (1962) found that intestine of ***Tor tor*** feeding on filamentous algae, gastropods, insects, sand and gravel, is 4 to 5 times longer than its body length and more convoluted than that of ***T. putitora*** which, according to Hora (1939), is more carnivorous than the former.

Table 9. Gut contents composition (%) of ***Tor tor*** (Desai, 1970)

Broad groups of gut contents	Volume (by eye estimation)	Occurrence methods	Index of Preponderance
Macrophytes	48.5 (1)	57.5 (1)	66.37 (1)
Molluscs	10.5 (3)	36.2 (2)	9.03 (2)
Algae	14.5 (2)	25.1 (5)	8.67 (3)
Insects	8.3 (4)	32.8 (4)	6.52 (4)
Sand and mud	7.8 (6)	34.6 (3)	6.39 (5)
Debris	7.9 (5)	14.8 (6)	2.79 (6)
Fruits	2.1 (7)	4.4 (7)	0.22 (7)
Fish scales, bones	0.2 (8)	1.6 (8)	0.01 (8)
Miscellaneous	0.2 (9)	0.7 (9)	Neg. (9)

Note: numbers in parentheses indicate the order of preponderance

Juveniles (95-200 mm in length) of ***T. tor*** from the Narmada River mainly subsisted on insects (53.8%), followed by molluscs (21.9%), macrophytes (4.7%) and algae (2.8%) (Desai, 1982). The intestine of juveniles was shorter than that of adult fish. For the food spectrum of adult and juvenile fish see **Figure 13**. Seasonal abundance of different types of food in ***Tor tor*** was also studied (Desai, 1970).

The role of ***Tor tor*** in biological control of aquatic plants is worth exploring and its subsistence on molluscs could help in controlling mollusc populations and consequently the infection of fish by trematodes (Desai, 1970).

Food composition (by volume) for different size groups of ***Tor tor*** from the Narmada River is given in **Table 10**. While the juveniles (95-200 mm) subsisted mainly on insects and molluscs, the grown-up fish fed on aquatic macrophytes, algae, molluscs and insects, in order of preference. There was a change from insectivorous to herbivorous diet as the fish attained a size over 200 mm. In subsequent size groups (281-760 mm), aquatic macrophytes and algae formed the main food.

In Lake Govindgarh near Rewa in Madhya Pradesh ***Tor tor*** fed in the lake margins and on the bottom (Pisolkar and Karamchandani, 1984). Fry and fingerlings (up to 160 mm) subsisted mainly on macrophytes (87.9-91.4%); the adult fish (over 300 mm), besides macrophytes (74.9%), fed on animal food such as insects, molluscs and fish matter (5.5%). The monthly trend of feeding intensity and condition factor was similar to that from the Narmada River.

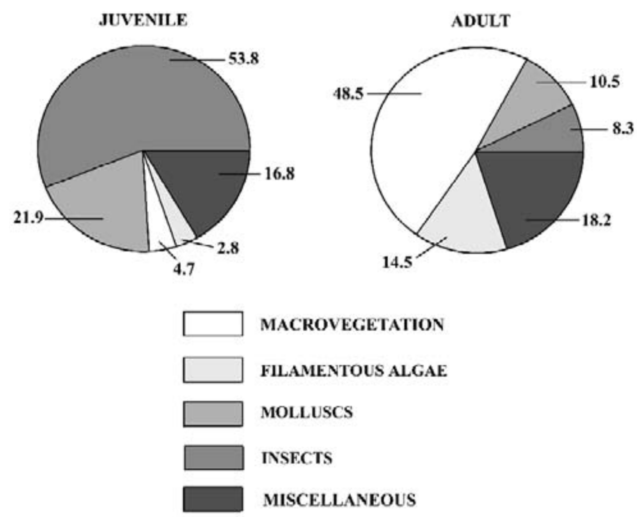


Figure 13. Food spectrum of adult and juvenile ***Tor tor***

The food of ***Tor tor*** was compared for four localities of India: the Narmada River at Hoshangabad, Lake Govindgarh (Madhya Pradesh), Lake Bhimtal (Uttar Pradesh), and the Bhagirathi River of the Garhwal region (Uttar Pradesh), the last two being in the Himalayas (**Table 11**). In the Narmada River and Lake Govindgarh the fish fed mainly on macrophytes (66.4-81.2%), but in the Himalayan uplands they preferred insects (22.6-35.8%) and algae (20.0-21.1%) to macrophytes (8.1-25.0%).

According to Verma (1965), gut contents of ***T. tor*** from impoundments of Madhya Pradesh showed that the fish is an omnivore feeding on macrophytes, insects and molluscs and as such it can comfortably

Table 10. Food composition in different size groups of ***Tor tor*** (Desai, 1982)

Size range (mm)	No. of specimens	Percentage by volume				
		Macrophytes	Algae	Molluscs	Insects	Miscellaneous
1	2	3	4	5	6	7
95-200	57	4.7	2.8	21.9	53.8	16.8
201-280	10	14.4	25.2	21.5	1.0	37.9
281-440	160	29.2	13.5	14.1	11.8	31.4
441-600	211	33.3	21.7	10.2	8.9	25.9
601-760	054	44.0	11.4	7.1	5.1	32.4

Table 11. Food composition of ***Tor tor*** from four localities of India (Desai, 1992)

Food items	Narmada river (Desai, 1970)	Govindgarh lake (Pisolkar & Karamchandani, 1981)	Bhimtal lake (Bisht & Das, 1981)	Bhagirathi river (Sharma, 1986-87)
Macrophytes	66.37	81.18	25.0	8.1
Algae	8.67	neg.	20.0	21.1
Molluscs	9.03	0.03	-	-
Insects and their larvae	6.52	0.12	35.8	22.6
Fish	0.01	0.22	-	-
Other food	3.01	-	7.0	7.9
Crustaceans	-	-	9.0	10.1
Diatoms and protozoans	-	-	-	10.5
Mud and sand	6.39	18.45	-	12.9
Worms			3.2	6.8

coexist with the major carps. Dasgupta (1990) studying the food of fish from the Simsang River (Meghalaya) found it to subsist mainly on algae and vegetable matter. The food habit changed from carni-omnivorous to herbi-omnivorous, which was also evident from the increasing relative length of gut (RLG) from 1.74 (101-150 mm fish) to 2.88 (301-350 mm fish). Sharma (1986-87) also recorded RLG values from 1.25 ±0.0253 to 2.180 ±0.0912 in ***T. tor*** from the Garhwal Himalayas. Bisht and Das (1981) considered ***T. tor*** as an ideal fish for cultivating in an ecosystem with rich entomofauna.

3.4.3 Growth rate

Length-frequency analysis and examination of scales and opercular bones of ***Tor tor*** from the Narmada River showed eight distinguishable modes of different age groups (0-7½ years) ranging from 160 to 565 mm (Desai, 1982). Scales showed growth rings in the form of grooves extending to posterior and lateral sides of the scale and being parallel to its margin (**Figure 14**). Their formation was annular, with rings being formed throughout the year. Rings were formed in response to different feeding intensities and stage of gonadal maturity. Poor feeding from July to October coincided with the peak spawning. Growth rings were laid during this period but since the breeding continued until March-April, the ring formation was likely to continue until that time. This explains the occurrence of marginal rings on the scale of ***Tor tor*** throughout the year. Temperature as a causative factor in ring formation was ruled out. The prolonged growth ring formation was observed on a wide range of fish, which also supported the fact that different fish bred at different times. A linear relationship between fish length and scale lengths was well established, with a high coefficient of correlation (r = 0.92). The lengths-at-ages were therefore back calculated from this relationship for I to VI years, which ranged from 196 to 565 mm respectively. As the first ring was seen in the scale of fish of 196 mm length, which was not the size of first maturity, it was inferred that the ring was formed due to physiological strain caused through change in the diet of fish from insect to plant matter.

Study of opercular bones also revealed regularly spaced markings with alternating transparent and opaque zones (**Figure 15**). The relationship between fish length and opercular length was linear with high correlation (r = 0.99). The lengths-at-ages of fish were back calculated using regression equation of these variables, which ranged from 226 to 580 cm for I to VII years of age respectively. The formation of marginal rings on operculum, as on scales, was not restricted to a specific period but was recorded throughout the year, with the reasoning that a ring was formed on account of feeding or spawning stress on the fish. The new technique of photographing the opercular bones for display of rings, using the same material, has been devised and described by Saxena (1981).

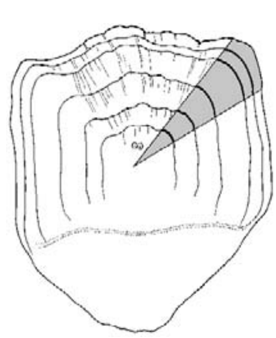


Figure 14. Scale of ***Tor tor*** with growth rings showing age 5+ years (Desai, 1982)

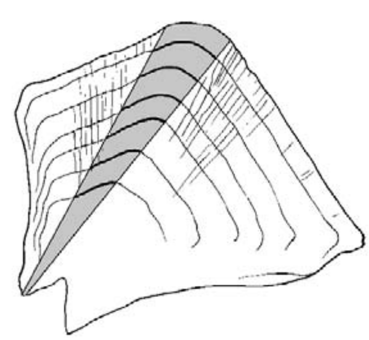


Figure 15. Opercular bone of ***Tor tor*** with growth rings showing age 6+ years (Desai, 1982)

The mean lengths of fish at ages of I to VII years calculated from length-frequency, scale and opercular bone analyses are presented in **Table 12** and depicted in **Figure 16**. The lengths derived from the three analyses were fairly comparable and therefore the average of the three values was taken as length-at-age.

Table 12. Mean length-at-ages of ***Tor tor*** (Desai, 1982)

Age (years)	Length-at-age (Peterson's method)	Length-at age (scale method)	Length-at-age (opercular bone)	Mean
I	219	196	226	214
II	281	295	291	289
III	344	383	359	362
IV	413	455	418	429
V	474	529	467	490
VI	523	565	525	538
VII	565	-	580	472

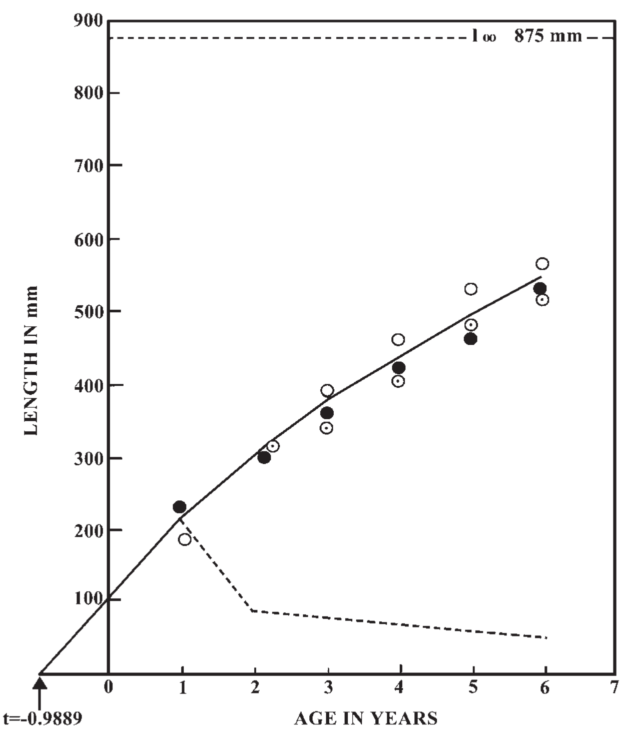


Figure 16. Growth curve of ***Tor tor***

Lengths-at-ages calculated separately for male and female fish showed no variation among the sexes.

The lengths-at-ages, weights-at-ages and annual growth of the fish are given in **Table 13**. Growth increment, relative growth and percentage of total growth are shown in **Table 14**.

Table 14 shows that growth of ***Tor tor*** in the Narmada River was very fast during the first year but it slowed down from the second year onwards. Figure16 shows a sharp drop in growth rate from fish of length 300 mm onwards. This is the size at first maturity, showing that with the commencement of maturation fish growth rate becomes slow. The growth pattern of ***Tor tor*** is described by von Bertalanffy's growth fit:

$$Lt = 875 \ [1 - e^{-0.1363(t+0.9889)}]$$

where Lt = length-at-age t; 1 = asymptotic length; e = base at the Napierian logarithm.

The condition factor was analysed separately for various size groups of fish (Desai, 1982). The 'K' value was relatively low (0.959 - 1.363) in smaller size groups but it gradually improved in bigger size groups, attaining a peak at mean length of 760 mm. The 'K' value suddenly decreased at fish length of 205 mm and then increased again, with downward inflexion at 340 mm.

The food study of the fish as discussed in section 3.42 shows insectivorous and plant diets of juveniles (95-200 mm) and adult fish (281-760 mm), respectively. The first inflexion in 'K' value at 205 mm is probably attributed to switch over in feeding habits,

Table 13. Mean length and weight-at-ages and annual rate of growth of ***Tor tor*** from River Narmada (Desai, 1982)

Age (years)	Length-at-age (mm)	Weight-at-age (g)	Annual growth (%)
I	214	100	160
II	289	260	77
III	362	460	74
IV	429	800	50
V	490	1200	33
VI	538	1600	19
VII	572	1900	

Table 14. Growth increment and relative growth of ***Tor tor*** from River Narmada (Desai, 1982)

Age group	Growth increment (mm)	Growth per month (mm)	Percent of total growth (relative growth)
0 - I	214	17.8	37.4
I - II	75	6.3	13.1
II - III	73	6.0	12.8
III - IV	67	5.6	11.7
IV - V	61	5.0	10.7
V - VI	48	4.0	8.4
VI - VII	34	2.8	5.9

during which process the fish loses its condition. The second inflexion of ‘K’ value at a mean length of 340 mm appears to be related to the size at maturity as discussed under section 3.12. But low ‘condition’ of males (0.869) as against that of females (0.937), shows that spawning strain is greater in males. The ‘condition’ of fish from the Narmada River was poor from July to December and coincided with the peak of breeding.

Pathani and Das (1980) stated that in ***Tor tor*** from Lake Bhimtal, the ‘K’ values were high during the breeding season (April to September) and lowest in January. During pre-spawning (February-March) and post-spawning periods (October-November), the ‘K’ factor was moderate due to the voracious feeding.

Pathani (1986-87), using scales and opercular bones, also studied age and growth of ***Tor tor*** from Lake Bhimtal. The results showed slower growth of fish in this cold-water lake as compared to that from the Narmada River. During the first five years the fish grew to 127.3, 242.0, 334.4, 414.6 and 478.0 mm respectively. Growth rings formed on scales and opercular bones in response to low water temperature and the consequent low feeding rate. Scales showed marginal rings starting from November (62.1%), with a peak in December (98.1%), gradually decreasing from January (81.8%) to May (23.4%). The formation of rings continued to a lesser degree from June to September and was nil in October. Pathani (1980, 1988) also aged the Lake Bhimtal fish using otoliths and vertebrae. The lengths-at-ages estimated by these methods fully corroborated those back-calculated from the analyses of scales and opercula.

3.4.4 Metabolism *

3.5 Behaviour (for feeding behaviour see 3.4.1; for reproductive behaviour see 3.1.3, 3.2.1).

3.5.1 Migration and local movements

Mahseers are local migrants which perform seasonal migrations within a short distance mainly for feeding and breeding. The limit of such migrations are determined by water temperature and floods. Mahseers prefer rocky pools and cooler temperature of the headwaters, moving up and downstream, depending upon the flood conditions. Most species of ***Tor*** spawn in clear upper waters in the post-monsoon months. The small number of adult fish recorded from the Narmada River at Hoshangabad during the peak breeding season (July-September) (Karamchandani *et al.*, 1967) suggests that the fish moved upstream in search of suitable spawning grounds. Beavan (1877) stated, that “when the rains begin these fish commence moving up the stream for spawning purposes”. Thomas (1897) found that some adult mahseers reached the upper reaches earlier in monsoon and subsequently bred there when floods receded. Hora and Nair (1944) mentioned mahseer entering small side streams for breeding and their descent into the main stream when the water begins to fall. The migratory habit of mahseer was also observed by Codrington (1946) and David (1953a). McDonald (1948) attributed these movements to the changes in water temperature and to seeking more congenial surroundings during the monsoon.

3.5.2 Schooling

David (1959) observed congregation of mahseers near temples. Such spots are declared sacred with prohibition on fishing. The fish which this convention aims to protect are mostly the mahseers. By constant artificial feeding and non-interference, the fish become almost tame. A congregation of mahseers near a bathing ghat, with temples along the bank of the Narmada River, was observed by Desai (1982) at Hoshangabad. According to his observations, fishing in this sector of the river was prohibited by the Municipal Committee and the fish was trained to accept artificial feed. People from Hoshangabad coming to the Sethani Ghat for an evening stroll could feed the big mahseer with gram, ground nut and dried stone-fruits and watch them feeding. The fish in this sanctuary were jumping out of the water to catch the feed thrown in the air.

3.5.3 Response to stimuli *

4. POPULATION (STOCK)

4.1 Structure

4.1.1 Sex-ratio

For the ***Tor tor*** of the Narmada River, up to a length of 350 mm, the ratio of females to males was 1:1 (Desai, 1982). Females, however, were more abundant in the size range of 351-550 mm. Fish longer than 550 mm were all females, and females also dominated the spawning stock (301-500 mm). A possible explanation for the dominance of females after 350 mm could be that females are more vulnerable to cast and gill nets.

There was a significant departure from a 1:1 ratio during the year, with females dominating the fish stocks most of the months. The highest numbers of females were seen during the quarters July-September and October-December, which coincided with the prolonged breeding of the fish. The females dominated all year around, with an overall sex ratio of 1 male to 3 females.

According to Chaturvedi (1976), the sex ratio of ***Tor tor*** from Lake Udaipur (Rajasthan) was equal during July-September, but overall females exceeded males by 1.9 to 1.0. The occurrence of more males in smaller size groups but dominance of females with increase in size (and hence age), as observed in the Narmada River, was also noted by Codrington (1946) and McDonald (1948) for mahseer in general.

4.1.2 Age composition

The ***Tor tor*** stocks from the 48 km stretch of the Narmada River showed eight age groups of 0 to 7½ years ranging from 160 to 565 mm (Desai, 1982). The higher age groups (III to VI), ranging from 346 to 506 mm TL and above contributed 18.2 to 19.7%, the smaller age groups (0 to II) ranging from 100 to 345 mm, only 1.6-14.7%. As seen from seasonal variation in age composition by weight, the smaller age group occurred in greater numbers from July to September (monsoon months) but from October to June the larger groups were more frequent in fish catches. On the contrary, by number, the lower age groups (0 to II) contributed more (12.3-21.7%) than the higher age groups (5.0-9.1%). The seasonal distribution of age groups by number was similar to that observed by weight.

Length frequency data for post-larvae and juveniles of ***Tor tor*** (discussed under 3.16), apart from showing breeding periodicity, also show early growth rate of fish representing '0' age group of pre-recruitment phase. From the monthly progression of modal lengths of fry and fingerlings as shown in Figure 6, it was estimated that the fish at the pre-recruitment stage had a growth rate of 8-10 mm/month. The length frequency data from commercial catches revealed that only fish of 70 mm and larger were vulnerable to commercial gears. This size fish were encountered for the first time in March and were the brood resulting from either the July-September or November-December spawning. The smallest fish of the commercial catch (70 mm), designated as 'O' group, appeared to be six months old.

The male fish mature in the second year, females in the second to third year. For the maximum age/size of the fish see 3.3.1.

4.1.3 Size composition

See section 4.1.2.

The length-weight relationships of male, female and juvenile fish of ***Tor tor*** from the Narmada River were as follows:

Males : $W = 0.000011\ L^{2.9851}$ or $\text{Log } W = -4.9647+2.9851 \text{ Log } L$; (r=0.96)

Females : $W = 0.000075\ L^{3.0522}$ or $\text{Log } W = -5.1263+3.0522 \text{ Log } L$; (r=0.99)

Juveniles : $W = 0.0032\ L^{3.2065}$ or $\text{Log } W = -5.4939+3.2065 \text{ Log } L$; (r=0.99)

The graph derived from the above equations assumed parabolic curve (**Figures 17** and **18**). There was no sexual variation in the weight up to 400 mm of length, but beyond that the 'condition' of females was better than that of males. Weight of male mahseer increased slightly less than the cube of its length, showing faster growth in length. Female mahseer did not deviate much from the cube law. The 'condition' of juvenile fish was better than adult fish, showing faster growth in weight than in length. The exponential value departing from the cube law in the case of males denotes their poor condition.

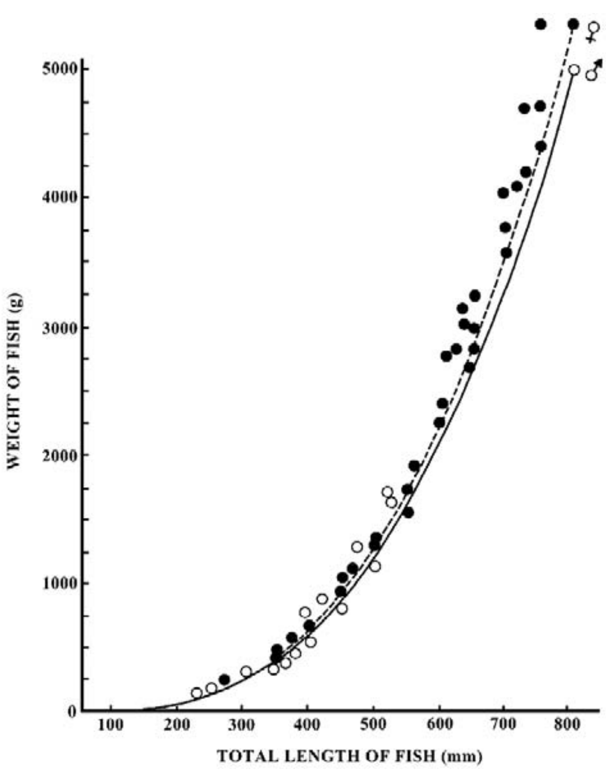


Figure 17. Length weight curve of adult male and female ***Tor tor***

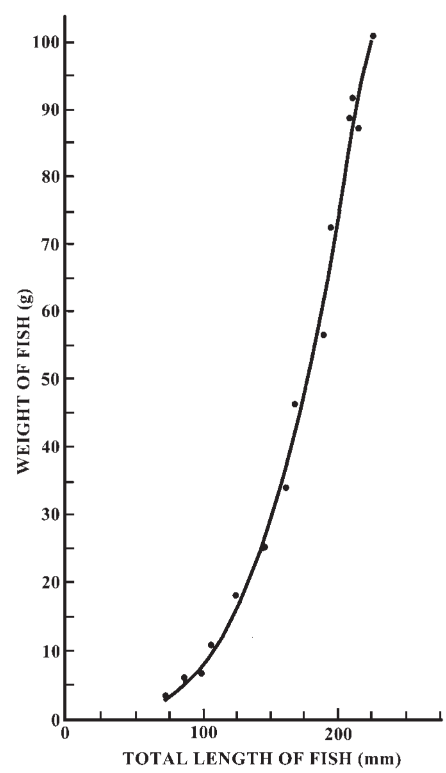


Figure 18. Length weight curve of juvenile ***Tor tor***

The length-weight relationships of males and females of this species from Lake Udaipur reported by Chaturvedi (1976) were:

Female : Log W = -5.9528 + 3.3927 Log L

Male : Log W = -5.3477 + 3.1609 Log L

In the above relationships, while the male fish were heavier than females up to 400 mm in length, the females were heavier in larger fish. This overtaking of male by female at 400 mm was probably due to the weight of female gonads attaining maturity, as also observed in the Narmada River by Desai (1982).

4.2 Abundance and density (of population)*

4.3 Natality and recruitment

4.3.1 Reproduction rates*

4.3.2 Factors affecting reproduction*

4.3.3 Recruitment

For the recruitment of fish in the Narmada River see 3.1.6. The catch curve for ***Tor tor*** from the 48 km stretch of the Narmada River around Hoshangabad (**Figure 19**) shows that recruitment to fishery commenced from the 0 year age group, and was completed by three-year-old fish (Desai, 1982).

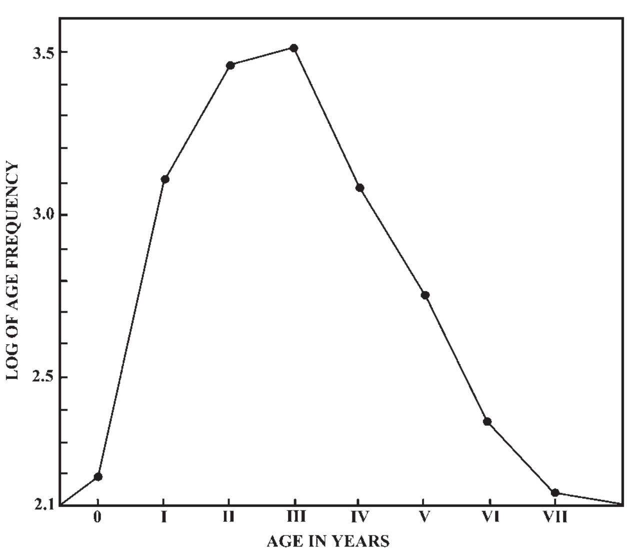


Figure 19. Catch curve of ***Tor tor***

4.4 Mortality and morbidity

4.4.1 Mortality rates

The steep right hand limb of the catch curve suggests that the natural mortality rate of fish steadily increased in the 48 km stretch mahseer fishery of the Narmada River. The mean length of fish (350 mm), also from this river stretch, indicates a high mortality rate and low survival. The total mortality and survival rates together with instantaneous rates of mortality of the fish are given in **Table 15**.

4.4.2 Factors causing or affecting mortality

Table 15. Mortality and survival rates of ***Tor tor*** from River Narmada (Desai, 1982)

Age group	Instantaneous rate of mortality	Survival rate	Total annual mortality rate
0 - VII	0.777	0.470	0.530
I - V	0.825	0.441	0.559

There has been a steady decline in mahseer fishery in the Nainital and Bhimtal lakes of the Kumaun region (Das and Pathani, 1978a). In Nainital water transparency is lower than in Bhimtal, as a result of a higher input of silt into the former lake. This causes a lower plankton production and consequently less food for fry and fingerlings. Lake Bhimtal has a higher production of mahseer and other fish. In Nainital, higher alkalinity, carbon dioxide, turbidity and pollution, and a low temperature are making this lake unsuitable for eggs and fry of mahseer. The decline of mahseer in these Kumaon lakes is mainly due to the progressive eutrophication coupled with some adverse hydrobiological factors.

The semiquiescent stage after hatching of ***Tor tor*** lasts six days (Kulkarni and Ogale, 1979; Kulkarni, 1980a). During this period the hatchlings do not swim freely but remain in large numbers at the bottom in corners and crevices, with their heads tucked away from the light due to being negatively phototropic, their tails vibrating and jutting out. In this condition the hatchlings are subjected to predation by many predators. The semi-quiescent stage appears to be the most critical in fish life and results in a heavy mortality.

4.4.3 Factors affecting morbidity *

4.4.4 Relation of morbidity to mortality rates *

4.5 Dynamics of population

In the past ***Tor tor***, known as ‘badas’ around Hoshangabad, constituted an important commercial fishery in the 48 km stretch of the Narmada River between Hoshangabad and Shahganj (Karamchandani *et al.*, 1967). This stretch of the river, passing through the hills of Satpura and Vindhya ranges, is rocky - an ideal habitat for mahseer. Annual landings of ***Tor tor*** from the 48 km stretch recorded for six years (1958-59 to 1963-64) are given in **Table 16**. During this period, a total catch of 47.619 kg was landed, of which 34.985 kg were at the Hoshangabad centre, and 12.634 kg at

Table 16. Fish landings of ***Tor tor*** from 48 km stretch of River Narmada

Year	Hoshangabad (kg)	%	Shahganj (kg)	%	Total (kg)
1958-59	6 578	80.6	1 583	19.4	8 162
1959-60	5 191	71.2	2 098	28.8	7 288
1960-61	5 054	78.5	1 380	21.5	6 434
1961-62	5 494	73.5	1 982	26.5	7 476
1962-63	6 873	78.8	1 839	21.2	8 712
1963-64	5 795	60.7	3 752	39.3	9 547
Total/Av.	34 985	73.9	12 634	26.1	47 619

Shahganj. The total annual fishery ranged from 6 434 kg in 1960-61 to 9 547 kg in 1963-64. The average annual yield at the two centres was 7 936 kg, of which Hoshangabad contributed 5 831 kg (73.9%) and Shahganj 2 106 kg (26.1%).

The annual landings of ***Tor tor*** from Ukai (Vallabhsagar) Reservoir in the state of Gujarat from 1975-76 to 1982-86 (**Table 17**) shows an increase from 1975-76 to 1979-80, followed by a decline.

Table 17. Annual fish landing of ***Tor tor*** from Ukai Reservoir (Gujarat State)

Year	Catch (kg)	%	Year	Catch (kg)	%
1975-76	15 798	6.55	1979-80	26 609	19.33
1976-77	15 931	7.80	1980-81	19 966	7.70
1977-78	7 442	5.01	1981-82	3 926	3.70
1978-79	10 812	5.25	1982-83	1 744	0.02

Fish catch statistics from Gandhi Sagar Reservoir on the Chambal River in Madhya Pradesh show that ***Tor tor*** proportion in the total catch increased from 9.35% (1964-65) to 15.20% (1966-67), which was followed by a decline to 1.0% by 1984-85. In Rana Pratap Sagar Reservoir on the same river the catches of ***Tor tor*** improved after the formation of the impoundment in 1973-74, followed by a decline (**Table 18**). The data for the three reservoirs show that ***Tor tor*** is not doing well in impoundments. This is not so in some reservoirs in the foothills of the Himalayas, which have ***Tor putitora***. In Gobindsagar, Pong and Pandoh reservoirs on the Beas and Sutlej rivers (Himachal Pradesh) the inflowing rivers and streams still provide spawning grounds for this species, and in spite of an active commercial fishery its stocks are maintained at a sustainable level (Raina and Petr, 1999).

Table 18. Landing and size composition of ***Tor tor*** from Rana Pratap Sagar Reservoir (Rajasthan)

Year	Mahseer catch (t)	Size composition % (length of fish in cm)					
		30-35	35-40	40-45	45-50	50-55	55-60
1972-73	2.6	-	-	-	-	-	-
1973-74	20.6	4.39	15.36	24.14	24.63	22.19	9.26
1974-75	10.0	-	19.54	32.87	22.75	17.70	7.12
1975-76	19.2	2.25	18.27	23.40	24.22	24.68	7.18
1976-77	12.2	-	-	-	-	-	-

4.6 The population in the community and ecosystem

See section 4.5 and other sections.

5. EXPLOITATION

5.1 Fishing equipment

5.1.1 Gear

Fishing gears used to catch ***Tor tor*** are cast, gill and drag nets, hook-and-lines (long line) and scare line. Being a good game fish it gives excellent thrill and excitement to anglers using rod-and-line, and therefore the anglers catch it only with rod-and-line using bait. The bait-taking habits of the fish provide good angling.

In the 48-km stretch of the Narmada River, ***Tor tor*** was mainly caught by using cast nets, gill nets and long lines. Cast nets were made of cotton of different thickness, with different mesh sizes, and provided with iron sinkers. Luring was also practiced. For this the fish were fed regularly for a few days to congregate them at one place. The assembled stock was then fished out using a cast net. Dry stone fruits were fed to the fish in March-April, due to the abundance of this food in summer. The gill nets were made of either nylon or cotton, of different lengths with varying mesh sizes. The net had no sinkers except for a master sinker. It had a master float of gourd locally known as 'tumbe' or 'loki' and other smaller floats of straw bundles. The length and height of the gill net was adjusted according to the operational depth of river water. The long line was a strong rope up to 800 m long, with 400-500 hooks attached. Filamentous algae, dragon fly nymphs, water bugs, earthworms, small fish, dry stone fruits and flour balls were used as bait. The long line was operated more commonly during monsoons when the operation of cast and gill nets was not possible due to flood conditions (Karamchandani *et al.*, 1967; Desai, 1982).

The fingerlings of ***Tor tor*** were collected from the Narmada River around Hoshangabad by scare line and drag net (Karamchandani and Pandit, 1964). A rope fitted with datepalm leaves was employed as a scare line and two cast nets were used as traps. The fingerlings of mahseer were trapped in two cast nets by dragging the scare line in shallow regions of the river. Drag net fishing is a modification of scare line fishing where the drag net is operated in conjunction with the scare line, made of coir rope and fitted with datepalm leaves. Drag net is made of an ordinary mosquito netting cloth. This fishing method was used from November to March to catch mahseer fingerlings for stocking.

Mahseers are fished in streams, lakes and reservoirs of the uplands using nets, traps and by poisoning. In many areas long lines are also used (Jhingran and Sehgal, 1978).

Nets

Cast net: The conventional cast net used in hill streams of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh is between 1.0 and 2.0 m in diameter, with mesh size varying from 1.2 to 3.0 cm bar to bar and having iron or lead sinkers.

Drag net: It is used for community fishing in conjunction with stake net or cast net, during dry season when the river water is low. A stake net is fixed across the shallow tail end of the pool and then the drag net is dragged down the pool from upstream by 50-100 fishermen. As the drag net approaches the stake net, fishermen cast their cast nets in the area thus enclosed between the stake and the cast net.

Seine ('bigha'): At the confluence of the tributaries with rivers Beas and Sutlej in Himachal Pradesh, seines ranging from 35 to 50 mm knot to knot in mesh are fixed across the entire width of the stream. The net is fixed at night and the catches are collected in the morning. 'Bigha' functions as a stationary gill net.

Stake net ('barpatta'): Stake net is fixed like a vertical wall across the stream to catch the downstream migrating mahseer and other fish. This net is specific to Himachal Pradesh.

Bag net ('kochbi' or 'saggan'): This is a dip net, the mouth of which is either circular or triangular in shape. These nets are used to catch the fish near waterfalls in Himachal Pradesh and Jammu.

Gill net: Usual size of a gill net is 75 m x 3 m with mesh ranging from 45 mm to 75 mm knot to knot. Gill nets are used in deep reservoirs and lakes.

Traps

'Chip': The 'chip' consists of a large or small platform made of split bamboo or sticks, either woven or tied together to provide interspaces of 37 mm square. The platform is placed in an inclined position under a low waterfall, either natural or created with the entire stream water falling over it. The height of the fall chosen for the 'chip' is such that none of the fish falling over it could possibly negotiate the fall. This is operated by 40-50 persons and it is used to capture mahseers migrating downstream.

'Uril': This is a conical-shaped trap made of fine split bamboo woven like a basket. Its length is 1.0-1.5 m. The mouth of the trap is at the broader end. The flow of a small stream is blocked by erecting a temporary weir of stones with an opening, and the trap is positioned at the mouth of the opening. Fry and fingerlings of mahseer carried downstream are caught by this method in Kangra, Hamirpur and Una districts of Himachal Pradesh.

Poisoning

Poisons made from seeds of some plants are thrown into the pools and the water is thoroughly stirred. The poisoned fish have no ill effect when eaten.

Recreational Fishing

Mahseer is the most popular game fish amongst the anglers in India. Since angling was a favourite pursuit of the British, Indian mahseers attracted the attention of anglers such as Beavan (1877), Thomas (1873, 1897), Dhu (1906, 1918, 1923) and Nevill (1915). The lakes of Kumaon hills were stocked with the fish by Sir H. Ramsay in about 1858 (Walker, 1888) for sport fishing. Codrington (1946) and McDonald (1948) wrote about its natural history and on special traits of the fish from an angler's point of view. Mahseer fishery maintains its fame among anglers in Britain. In the 1970s three Englishmen travelled overland to India in search of mahseer, fishing the waters from Kashmir to Tamil Nadu for eight months until they found mahseer in the waters of south Karnataka. This adventure was described by Ghorpade (1978). Kulkarni and Ogale (1979) considered mahseer the noblest sport fish of India, a great favourite of anglers, both from India and overseas.

There are three methods for capturing mahseer: fly fishing, spoon fishing, and bait fishing.

(a) Fly fishing: Fly fishing or fly casting is a method where artificial fly is used to hook the fish with the help of rod-and-line.

(b) Spoon fishing: Spoons, like flies, are artificial metallic shining lures used basically to fish 'heavier' waters where mahseer occurs. Spoon fishing for mahseer is generally grouped into three major types, viz. heavy fishing, medium fishing and small fishing. In heavy fishing, the angler looks for big fish (above 13.5 kg). Mahseer fishing in rivers of northern India generally is of a medium type. Small fishing is the most widely used angling for mahseer as the other two methods are arduous and even risky.

(c) Bait fishing: Both natural and artificial lures are used in bait casting. The natural baits are earthworms, minnows and insects.

In large reservoirs such as Gandhi Sagar and Ukai fishing is done using gill nets of varying mesh sizes. Mahseer is caught along with the Indo-Gangetic major carps.

5.1.2 Boats

In most rivers and reservoirs fishing is done from small light boats, known as 'dongi' which are usually 6 m long, 1.5 m wide and 45 cm deep. In the Narmada River, fishing is done from flat-bottom boats 6-9 m long and operated by 4 men.

5.2 Fishing areas

5.2.1 General geographical distribution

See section 2.1.

5.2.2 Geographical range

According to Karamchandani (1972), the best places for mahseer fishing are:

(1) the junctions of rivers especially those with a difference in water temperature, where one of the two rivers is discoloured by melting snow;

(2) rapids of many forms, sizes and depth, at places where the backwaters and rapid waters meet forming swirls and eddies along the edges;

(3) the water above a rapid and at the tail of a pool having a depth of about 0.9 to 1.2 m and a smooth flow over large boulders, gaining in velocity as it approaches the rapid.

5.2.3 Depth range

In rivers and reservoirs, fishing nets are operated both in deep and shallow waters. Gill nets are normally operated at a depth of 3 to 4 m. Sometimes the gill nets are also set deeper. In Rana Pratap Reservoir Chaudhary (1978) captured mahseer from 11 to 12 m depth. Anglers generally prefer to cast their tackle in 1 to 2 m deep waters.

5.3 Fishing seasons

5.3.1 General pattern of fishing season

In northern India, the best fishing season for mahseer is from February to April for the large rivers, and October and early November for small rivers not affected by snow-melt waters. Early hot weather is known to be best. In rivers of Mumbai (Bombay), Madhya Pradesh, Mysore and Chennai (Madras), the season for mahseer fishing with spinning baits and fly is generally from the time the rivers begin to clear after the monsoon floods (McDonald, 1948).

In the Narmada River around Hoshangabad there is a cast net and gill net mahseer fishery. Since the operation of these nets is possible when the river is largely stagnant, which is in the summer and winter months, mahseer is caught predominantly from October to June, over a period of nine months. The peak fishery may be at any time from November to April; August and September have the lowest fishing intensity (Desai, 1982).

5.3.2 Dates of beginning, peak and end of season

See section 5.3.1.

5.3.3 Variations in dates or duration of fishing season

See section 5.3.1.

5.4 Fishing operations and results

5.4.1 Effort and intensity

The catch-per-unit-of-effort for ***Tor tor*** from the 48-km stretch of the Narmada River around Hoshangabad is given in **Table 19**. The unit-of-effort of cast net ranged from 0.068 kg (1958-59) to 0.194 kg (1963-64). The yearly trend of unit-of-effort as compared with the total annual mahseer fishery showed that mahseer landings were highest in 1963-64 (9 547 kg). The unit-of-effort progressively increased from 1958-59 to 1963-64 and then dropped in 1964-65. However, this trend was not exhibited by the fishery which was more or less uniform with slight variations. It was concluded that mahseer stocks in the 48 km stretch were not adversely affected by the fishery during the 1958-1966 period.

Table 19. Catch-per-unit-effort and percentage of ***Tor tor*** in cast net/gill net fishery from Narmada River (Karamchandani et al., 1967)

Year	Catch-per-net-per-hour (kg)		Percentage in fishery of	
	Cast net	Gill net	Cast net	Gill net
1958-59	0.068	-	27.54	-
1959-60	0.091	-	29.58	-
1960-61	0.091	-	32.23	-
1961-62	0.104	0.108	30.32	52.44
1962-63	0.122	0.181	29.93	43.74
1963-64	0.194	0.132	32.54	38.28
1964-65	0.109	0.171	25.87	31.64
1965-66	0.131	0.112	31.35	28.61

5.4.2 Selectivity

The catch statistics from the 48-km stretch of the Narmada also provide some information on gear selectivity. Since the catch of mahseer using long line was negligible, only data from cast and gill nets were taken into consideration. The percentage composition of ***Tor tor*** in the catches of cast and gill nets as shown in **Table 19** indicate that the species constituted an outstanding major fishery. While in cast net the species made up 25.9- 32.5%, in gill net operation it contributed 28.6-52.4% of the total catch. The poor results of long line fishing suggest that the fish keep largely to the bottom, where it feeds.

5.4.3 Catches

Monthly landings of ***Tor mahseer*** at Hoshangabad and Shahganj centres, coming from the 48-km stretch of the Narmada, are given in **Table 20**. The data show that the fish supported an important fishery all the year round except monsoon months. It was poor from July to September, improved considerably from October onwards, to become outstanding until June. The fishery attained the peak at any time from November to April. Every year the mahseer fishery in the Narmada around Hoshangabad extended over 9 months.

At the Hoshangabad centre during the period 1958-66, the species contributed on average 28.0% to total landings and 46.5% to carp landings (**Table 20**). Monthly variations in percentage composition show that in winter and summer months the percentage in total landings ranged from 25.6 to 38.2% but during monsoons it was only 11.5 to 15.0%.

Table 20. Monthly landings of ***Tor tor*** from 48-km stretch of Narmada River (1958-59 to 1962-64)*

Month	Total catch (kg)	Percentage composition in	
		Total fishery	Carp fishery
1	2	3	4
September	1068.89	13.9	40.7
October	2784.67	25.6	53.5
November	4190.00	30.5	53.5
December	3028.42	29.4	47.3
January	4713.23	38.0	57.6
February	4278.05	38.2	52.5
March	4511.37	35.0	51.3
April	3766.96	35.7	47.6
May	3636.92	33.5	46.1
June	4858.96	30.9	44.7
July	1403.20	15.0	32.3
August	666.34	11.5	32.2
Average:		28.0	46.5

* Data of 1962-63 not included

6. PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative) measures

6.1.1 Limitation or reduction of total catch *

6.1.2 Protection of portions of population

Closed areas: Conservation measures for protection of mahseer fishery are adopted on lines similar to those for the major Indo-Gangetic carps. Certain areas have been declared as “protected waters” or sanctuaries and closed for fishing. Sanctuaries have been declared in Assam, Bihar and Punjab. Uttar Pradesh and Madhya Pradesh also observe restrictions on fishing in some waters.

Closed seasons: These are followed in Bihar, Uttar Pradesh, Rajasthan and Madhya Pradesh. In all large reservoirs fishing is closed from June-July to end of September to protect the fish during their breeding migration.

Limitations on size or efficiency of gear: In Delhi, every year since 1948 restrictions have been imposed on fishing except with rod-and-line, hand lines, long lines from 1 July to 31 August, and the use of net with a mesh size of less than 37 mm square is also prohibited. In Indian reservoirs, generally, the minimum mesh size of the nets permitted is 25 mm.

In 1956, the Punjab State Government prohibited the catching of mahseer of a size smaller than 25.4 cm in length. In Delhi, the capture and sale of this fish below 20.4 cm in length has been prohibited since 1948. The state of Uttar Pradesh has prohibited, since 1954, the capture and sale of mahseer fingerlings of 5.1-25.4 cm from 15 July to 30 September and of breeders from 13 June to 31 July in certain prohibited areas, except with a license issued by the proper authority. In Madhya Pradesh, the minimum limit of 22.9 cm for the capture of mahseer has been imposed since 1953.

Fish sanctuaries: At temple sanctuaries established by tradition, mahseers are protected from illegal poachers by many people. Several such sanctuaries exist in different parts of the country, the most outstanding being at Hardwar and Rishikesh temples on the banks of the Ganga River after its confluence with the Alaknanda River. In Madhya Pradesh too, there are sanctuaries at Kapileshwar, Mangalnath, Sahastradhara, etc. In Maharashtra, fisheries is banned in stretches of the Indrayani River at Alandi and Dehu, and the Bhima River at Pandharpur. In Karnataka, sanctuaries exist at Sringeri (Bhadra River), Srirangapatnam, Ramanathapuram and Chipalgundda (Cauvery River) and Shimasha (Sharavathi River). These fish sanctuaries, like those of wildlife, are useful in protecting the mahseer in fair weather, but because they cover only a section of a river the fish move out of them when the rivers are in spate. The Fisheries Department of Karnataka is now leasing out some sections of the rivers to angling associations. One such organization, the Wildlife Association of South India (WASI) at Bangalore, manages and protects mahseer in the Cauvery River (Mendonca, 1993).

6.2 Control or alteration of physical features of the environment

6.2.1 Regulation of flow *

6.2.2 Control of water levels *

6.2.3 Control of erosion and silting *

6.2.4 Fishways at artificial and natural obstructions

There are some successful mahseer fish ladders on the Ganga River at Hardwar (Kulkarni, 1981), but elsewhere fish ladders have proved ineffective. A thorough study on the migration behaviour of mahseers is needed, which could serve as a base for the design of a species- or genus-specific fishway design. Some of the existing fishways have been found to function more like fish traps rather than assisting the fish to move upstream.

6.2.5 Fish screens *

6.2.6 Improvement of spawning grounds

One of the main reasons for the decline of mahseer is the destruction of this fish by illegal means such as the use of explosives and killing of brood fish in the spawning season. The fish has suffered also from the change in the ecological condition of some river systems where dams have been erected. While such dams are no doubt beneficial to the country in several ways and the expansion of water bodies is advantageous for some fish and fisheries, migratory fish such as mahseer, which used to visit clear-water streams for breeding, may no longer reach them. With an increasing number of streams being used for reservoirs, the traditional breeding grounds of the mahseer are lost. Other streams, excluded from the developmental activities, are affected by harmful effluents which kill especially fish fry and fingerlings. The combination of such impacts adversely affects the fish fauna and mahseer in particular. The only remedy is to use artificial methods of propagation and raise fingerlings in hatcheries for their release in natural waters.

Kulkarni and Ogale (1979) studied breeding habits and conducted experiments on artificial propagation and rehabilitation of ***Tor khudree*** in the hydroelectric reservoirs of the Tata Electric Co. at Lonavla, (Maharashtra) which has proved to be a great success. This was the first attempt to study biology of mahseer by a biologist in the field, although Khan (1939) and Ahmad (1948) attempted it on a small scale. Kulkarni (1980) used the same method of artificial propagation successfully for ***Tor tor***, transplanted from the Narmada River in fry stage to Lonavla Reservoirs.

6.2.7 Habitat improvement

In 1871 the Superintendent of Dehra Dun reported on the state of mahseer conservancy in the following terms (Atkinson, 1973): “Breeding fishes are destroyed in great numbers and the small fry are also largely captured ...” implying that mahseers were not cared for by the locals. The National Commission on Agriculture in its 1976 report on fisheries, and Sharma (1983) noted the general decline in the mahseer fishery due to indiscriminate fishing of brood stock and juveniles and the adverse effects of river valley projects. It recommended extensive survey and detailed ecological and biological investigations. Two ardent anglers, M.L. Mehta (Times of India, 6.6.76) and Melvil Demellow (Sunday Times of India, 19.7.81), gave a vivid picture of the wanton destruction of mahseer in the rivers near Dehra Dun and called for a ‘Save Mahseer’ campaign. For conservation of mahseer, Sehgal (1971) proposed protection of juvenile mahseer, and collection of seed and stocking of lakes, reservoirs and ponds.

The decline of the mahseer fisheries in the Kumaun lakes due to indiscriminate fishing of brood stock fish and juveniles had already been reported by Raj (1945). Observations on pollution effects, low fecundity and cannibalism of the fish followed (Pathani, 1977, 1978; Das and Pathani, 1978).

Already in the 1960s, in Madhya Pradesh, particularly in the Narmada River near Hoshangabad and in the Tapi River near Barhanpur (Karamchandani *et al.*, 1967), landings of ***Tor tor*** were declining. More encouraging reports came from Gandhi Sagar and Rana Pratap Sagar reservoirs on the Chambal River, where mahseers were still plentiful. Valsangkar (1993) has observed good mahseer fishery for ***Tor khudree*** in Bhandardhara Reservoir, and for ***Tor mussulah*** in Shivajisagar Reservoir (Maharashtra). While in Bhandardhara Reservoir on the Pravara River the fish formed 11.6% in the total catch, in Shivajisagar on the Koyana River it contributed 20% to the total catch. Fortunately, the spawning grounds of mahseer upstream of these reservoirs have not been destroyed, this being the main cause for good spawning and for sustaining their fishery in both reservoirs.

Sport fishermen and fishery biologists have greatly contributed to the knowledge of the behaviour of mahseers. It is now up to specialists to fill in the gaps and to challenge the authorities to improve mahseer habitats.

6.3 Control or alteration of chemical features of the environment *

6.4 Control or alteration of biological features of the environment

6.4.1 Control of aquatic vegetation

Adult ***Tor tor*** mainly subsist on aquatic vegetation and therefore some plant material in their habitat is essential. But excessive growth of aquatic plants is harmful.

6.4.2 Introduction of fish foods (plants, invertebrates, forage fishes)

No mahseer foods are known to be introduced into their habitat.

6.4.3 Control of parasites and diseases

Parasites and diseases of this fish are yet to be studied. Infection with the digenetic trematode ***Isoparorchis*** sp. was reported from ***Tor tor*** in the Narmada River (Desai, 1982, 1993). The fish ***Pangasius pangasius*** is known to control the molluscs serving as intermediate host of the above parasites, and its presence with mahseer is therefore recommended.

6.4.4 Control of predation and competition

In culture conditions mahseer nursery, rearing and broodstock ponds should be free of all predators. Periodic checking of the growth of hatchery stocks would reveal if any predators are present.

6.4.5 Population manipulation*

6.5 Artificial stocking

6.5.1 Maintenance stocking

Since breeding of tor mahseer in confined waters is no longer satisfactory for survival of spawn and growth of juveniles, its repeated stocking even in large water bodies is essential.

6.5.2 Transplantation; introduction

Development of cold-water fisheries: ***Tor tor***, being a cold-water species, has a significant role to play in the development of cold-water fisheries. cold-water lakes of the uplands are an ideal place where this fish may be transplanted and introduced. Since there are relatively few people in the hills who can afford red meat, development of fishery in upland lakes of the Himalayas, Ghats and the Deccan Plateau needs to be encouraged. Reservoirs with clear water, rocky beds, submerged aquatic plants, filamentous algae, molluscs and insects provide a suitable environment for mahseer (Desai, 1982). Reservoirs Tawa and Barna in the Narmada River basin have been stocked with ***Tor tor*** by the Madhya Pradesh State Fisheries. Two reservoirs on the Chambal River (Gandhi Sagar and Rana Pratap Sagar) are also being stocked with mahseer.

Kulkarni (1991) suggested the following steps be taken for conservation of fish species in suitable new reservoirs :

(a) a fish farm should be established in close proximity to every new dam as part of the reservoir project budget;

(b) several fish-farm ponds should be reserved for mahseers;

(c) the fish should be bred either by collecting spawners from the streams joining the reservoir and stripping them for artificial fertilization of eggs, or by raising them in farms and breeding them with the help of pituitary hormone or otherwise;

(d) hatchlings should be grown to the fingerling stage and released into the reservoirs and downstream waters.

No total ban on fishing for mahseer is proposed. Implementation of these steps should assist in the preservation of mahseer and in its sustainable harvesting.

7. POND FISH CULTURE

7.1 Procurement of stocks

The mahseer fry are collected from the Narmada River during winter by the State Department of Madhya Pradesh Fisheries (Karamchandani and Pandit, 1964). In the past Narmada was the only river in India where mahseer seed was regularly collected from October to January for many years. Hundreds of thousands of fry and fingerlings were collected and stocked in ponds (Dubey, 1959).

Ogale and Kulkarni (1987) commented that collection of mahseer spawners could be a problem. However, in Walwhan and Shirawta lakes where they conducted most of their studies, the spawners could be easily collected due to favourable environmental conditions. Both lakes are surrounded by hills and the rain water is running through small ravines. The temporary streams then cascade into the lakes. Gravid fish are attracted by the sound of running water and its high oxygen content, but being unable to ascend the steep and rapid flowing streams, they keep to the shallow margins of the lake where they are easily captured by gill nets or cast nets.

7.2 Genetic selection of stocks*

7.3 Spawning (artificial, induced, natural)

Since 1970 the Tata Electric Companies (TEC) fish-seed farm at Lonavla, Maharashtra, has carried out artificial propagation, rehabilitation and conservation of ***Tor khudree***, ***Tor tor*** and ***Tor putitora***. The system of hatching eggs of ***Tor khudree***, ***T. mussullah***, ***T. tor*** and ***T. putitora*** in India at the Lonavla hatchery, Maharashtra, involves cement cisterns, wooden floating trays and perforated pipes. The pipes are punctured at regular intervals to provide oxygenated water directly into the trays and on the eggs (Ogale, 2002). About 30 000 eggs can be conveniently accommodated on each tray, this making a total of 240 000 for each hatching tank. In the 1970s both ***T. khudree*** and ***T. tor*** were successfully bred using hypophysation. Successful artificial breeding of ***Tor putitora***, a Himalayan species, was achieved in the same farm in 1995 and 1996 (Ogale, 1997). The Department of Fisheries of the State of Karnataka procured about 150 000 advanced fry/fingerlings of ***Tor khudree*** from the TEC's fish farm and released them into the Cauvery River. The Fish Farmers Development Agency, Yadavagiri, Mysore, also released 30 000 young mahseer into this river (Shanmukha, 1996).

Presently, ***Tor tor*** and ***Tor putitora*** are bred on a small scale in Bhimtal (Uttar Pradesh), producing 50 000 fingerlings annually. There is a programme for further development of mahseer fishery in the Kumaon lakes Bhimtal, Sattal and Naukuchiatal, and mahseer fingerlings are also needed for the rehabilitation of stocks in the rivers Yamuna, Nayar, Kosi, Saryu and Ganga (at Rishikesh and Hardwar) (Pandey, 1996).

At Lonavla fish farm, ***Tor putitora*** was also successfully bred for the first time using ovaprim. Mahseer fry, collected from wild waters of Himachal Pradesh in 1991, by the 1992 monsoon season had produced 500 fingerlings which were released in Lake Walwhan in the Western Ghats. They matured in 1995, when they were injected with ovaprim. This produced fertilized eggs, and subsequently fry. The experiment was repeated on five females during the 1996 monsoon, resulting in approximately 20 000 fry. The fry of 1995 were transferred to Jammu to the Anji fish farm, where they grew successfully to the fingerling stage (Anon., 1997a). Since 1997 at Lonavla, Maharasthra, India, ***Tor*** spp. adapted to captive pond conditions and have been bred using a single injection of Ovaprim. Stripping was done after 12 hours. The hatching success has been over 90% (Ogale, 2002).

Cross-breeding between ***Tor tor*** and ***Tor khudree*** has also been reported. Hybrids between ***T. khudree*** and ***T. tor*** (F_1 generation) were bred without hypophysation (Ogale and Kulkarni, 1987). Three-year-old hybrids of about 900 g were then stripped in early August 1986, and fertilized without the administration of pituitary gland extract or any other hormone. This was a milestone in breeding mahseer in confined waters without injections.

Natural spawning of ***Tor tor*** has not yet been observed.

7.4 Hybridization

Tor khudree and ***Tor tor*** were successfully hybridized with each other by using males and females of either species. The characteristics in both cases were intermediate as regards colour and body form. The rate of growth is similar or slightly better than in pure strains but the hybrids are more agile. Hybrids were also produced from ***T. putitora*** and ***T. mussullah***. F_1 generation could be bred with hypophysation and sometimes even without it when provided with a rich protein diet, feed additives, exercise and running water. The eggs of F_1 generation could be fertilized successfully with the milt of the pure strains of mahseer to produce an F_2 generation (Ogale, 2002).

7.5 Holding of stock

See section 7.3.

At present the most imperative measure for protection of mahseer stocks is the enforcement of the ban on illegal fishing methods, including fishing for broodstock and juvenile fish.

7.6 Pond management (fertilization, aquatic plant control, etc.)

In properly managed village ponds, ***T. khudree*** in Maharashtra, India reach 600 to 900 g in one year, or even more, but elsewhere (Sikkim) it grew to 750 g in 3 years (Ogale, 2002).

7.7 Cage culture

The first trials with cage culture of ***T. khudree*** and ***T. putitora*** were carried out in 2001 in Walwhan Lake, Maharashtra, India. The stocking density of fingerlings, each of 35 to 40 g, in net cages of 3 x 3 x 3 m, were approximately half a million per hectare. The fish, fed twice a day for 10 to 15 minutes with pelletized feed, grew to an average of 170 g in 5 months (Ogale, 2002).

7.8 Food and feeding

In trials with monoculture of ***Tor putitora*** in ponds at Lonavla, fingerlings were given pelletized feed made of rice bran, groundnut cake and fishmeal (30:30:40), with a mineral mix. The average growth was 110 and 90 g at stocking densities of 10 000 and 20 000/ha, respectively, at the end of eight months. Water temperature during the growing period was between 24° and 28°C. Based on the growth preference, conversion and feed utilization, 40% is the optimal protein requirement. Mahseer growth was higher in composite culture with Indian major carps than in monoculture. Since mahseer accepts pelleted feed and is capable of utilizing it efficiently, the species can also be used in cage culture (Ogale, 2002).

7.9 Disease and parasite control

Little information is available. Occurrence of ***Isoparorchis hypselobagri*** in ***T. tor*** from the Narmada River was discussed above. Malhotra (1982) reported a nematode host parasite from ***T. tor*** of Garhwal Himalayas, observing decrease in nematode numbers with decrease in fish weight. Sati (1986) recorded the fungal species ***Achlya flagellata*** being pathogenic on ***Tor tor***.

7.10 Harvest *

7.11 Transport

As the minimum hatching period is 60 hours, sufficient time is available for transporting eggs even over long distances. ***T. khudree*** eggs were successfully transported by air in moist cotton from Mumbai to Bangalore (Kulkarni and Ogale, 1979). Fertilized eggs were allowed to harden for 24 hours, then placed on moist cotton in two or three layers in perforated boxes and then packed in tins. In 1987 mahseer fry were successfully sent by air to the Laos PDR in Southeast Asia for stocking the Mekong River basin, and in the early 1990s fingerlings of ***Tor putitora*** were transported to Papua New Guinea.

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